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Apparent Quality of Alternative Halftone Screening When Compared to Conventional Screening in Commmercial Offset Lithography

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APPARENT QUALITY OF ALTERNATIVE HALFTONE SCREENING WHEN COMPARED TO CONVENTIONAL SCREENING IN COMMERCIAL OFFSET LITHOGRAPHY

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ABSTRACT

Printers are still concerned with craftsmanship and are always looking for means to produce faster print jobs with improved quality. The invention of new halftone screening techniques is one of the methods imaging companies have used as an attempt to improve the quality of the printed piece. These techniques can possibly improve the aesthetic qualities and fidelity of printed reproductions, therefore printers and students of printing need to study these techniques to ensure that the benefits outweigh the costs of implementation.

This experimental study was conducted to measure the quality of printed halftones that were screened with three different dot structures; conventional, alternative (XM) at 240 lpi, and alternative (XM) at 340 lpi. The printing of the halftones and tone scales was completed using accepted printing practices.

The analysis was focused on two questions; is there a difference in the tone scales created with the use of the alternative screening when measured with print industry equipment, and is there an improvement of the apparent quality of the halftones when evaluated by members of the print community and laypersons?

With the use of a densitometer and a spectrophotometer, the tint patches and tone scales were measured to determine a difference in color, density, print contrast, and dot area. Through statistical analysis, it was determined that a significant difference was created with the use of different screenings.

The Delta E values were also calculated with the collected CIELab measures. Delta E is the measure of the color difference between two colors. If the value calculated is

above two and a half or three, then the difference should be perceptible by the human eye. Overwhelmingly, the Delta E values show no humanly perceptible difference.

When evaluating the apparent quality of the halftones, many people reported that they saw no difference; the average number was thirty-two percent for printers and forty-four percent for non-printers. The participants who did perceive higher quality in one versus the other were fairly equally spread across the three screening methods and quality factors.

Therefore, the only conclusion that can be drawn from this research is there is a measurable difference in the screening methods but the difference is humanly imperceptible and is not commercially significant for commercial offset lithography.

DEDICATION

I would like to dedicate this dissertation to those of you still struggling to climb the educational tower. With perseverance, a well-chosen committee, a great deal of hard work, and an open mind, you will find yourself not only at the top of the tower but also, inside sipping cocoa and roasting marshmallows sitting on the hearth of a stone fireplace next to a warm and cozy fire. Only a few have made it into this country club of esteemed intellectuals. This is the last step in receiving your bid to join. You will soon be one of them. Good luck and keep climbing. If all goes as planned I may see you there. I will be the guy with the giant cheesy grin asking you to pinch me as assurance I'm not dreaming.

I have a special dedication to my loving wife Nikki. How could I possibly write everything inside of me that expresses my gratitude and love for you? I am grateful to God for every minute of my life with you. You have inspired me to be a better man since the moment I met you. See you at the Hampton's.

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Sometimes we forget how the little things we say and do will affect those around us. The many conversations, lectures, and activities bring us to the point in our lives where we either say, “I am proud of who I am” or “I wish I had done things differently”. I am proud of whom I am today and I owe it to so many people that if I thanked all of them, I wouldn’t be able to bind this dissertation. Thanks to all of you who have graced my life with your presence and helped me along the journey we call humanity.

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14. My mom, Kay Lynn Oliver, for her never ending accolades and heaps of praise for a job well done, teaching me to care about others, and showing me how to talk to strangers and offer kind words. Teaching is in my blood, probably from seeing your excitement and enthusiasm for the profession from some of my earliest memories. Mom, I finished this one and I must have done a great job because it took forever.
15. Thank you Lord, for all before and after this expression. I praise your name. Jehovah God our Father and Jesus Christ our Savior. Thank you Lord.

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CHAPTER 1

INTRODUCTION

Background

The Graphic Communications industry has developed into one of the largest industries in the United States. This ranking includes all companies involved in the creation and production of images and text such as labels, magazines, books, signs, and packages. Also, the graphics industry is responsible for the printing of flooring, draperies, wallpaper, clothing, and faux wood grain on furniture. A sighted person would find it difficult to say they could get through a day without being influenced by the graphics industry.

Lithography, invented in 1798 by Alois Senefelder, has become the most used method of printing over the last century as a result of the introduction of the offset lithographic press, invented by Ira Rubel in 1903. The invention of photography by Joseph Nicephore Niépce, a French scientist, who produced the first photograph around 1827-28, (http://www.niepce.com/) prompted Henry Talbot of England to produce the first halftone screen in 1852. Halftoning converts the original photograph into a series of dots of varying size to simulate tonal difference, displaying detail in the photograph. Darker areas of the photograph were printed with larger dots and lighter areas were printed with smaller dots. These different sized dots absorb the light reflecting from the paper in varying amounts thus giving the illusion of different shades of gray while printing with only black ink. (Kipphan, 2001)

Conventional, amplitude modulated (AM) screening continues to be the standard screening method with modifications in its production from photographic film processes to laser imagesetters to digital direct to press technology allowing a lithographic plate to be imaged directly on the press.

Ongoing research continues in an effort to produce better quality halftones by changing the shape and size of the dot. Jesus Hill of Guadalajara, Mexico is currently developing software that allows him to change the shape of each dot within a specific range. His efforts are an attempt to increase the quality of halftone reproduction for the newspaper industry. Agfa Corporation has been a pioneer in developing new halftoning techniques including CristalRaster® stochastic, a frequency modulated (FM) screening method, and Sublima® (XM), a hybrid method combining FM screening in the highlight and shadow areas of the photograph and AM screening in the midtones of the photograph. (Agfa, 2003) Creo has developed Stochatto® as their FM screening technology incorporating dots as small as ten microns throughout the halftone. (Blondal, 2003) The research and development continues in an effort to improve the quality of the halftone reproduction.

Statement of the Problem

The greatest challenge with image capture and reproduction, regardless of the device, is the tonal range. The tonal range of the original image is typically greater than the capability of the output device to reproduce its full range of tones. Therefore, the tonal range must be compressed into the range of the output device. This is called tone range compression. (Bohnen and O'Leary)

In the printing world, how good is good enough? Acceptable quality for halftones has become photographic print quality. With any printing method, printers are attempting to approach photo quality. A digital prepress operator will start with a print, slide, or digital photograph and try many methods in the graphic arts recipe book to achieve a reproduction as close to the original quality as possible. With all of the different possibilities for screening (line screen and nature of the dot), scanning, imagesetting, platesetting, and direct to press to name a few, printers and graphic communications hardware and software inventors are intent on improving the apparent quality of the halftone.

Significance/Purpose of the Study

The purpose of this study is to determine if significant improvements can be made in halftone reproduction by implementing an alternative screening (XM) method when compared to a conventional (AM) screening. The data from this independent comparative analysis will enable printers to make a more informed decision when considering an investment in an alternative screening method.

Research Questions

Research Question 1

Does using the alternative (XM) screening method significantly improve the apparent quality of halftone reproduction when compared to conventional screening method when reproduced on coated paper using an offset lithographic press?

Research Question 2

Will using the alternative (XM) screening method significantly change the measured values, (i.e. Lab values, Delta E, dot gain, and print contrast) when compared to conventional screening method reproduced on coated paper using an offset lithographic press?

Research Hypotheses

Research Hypothesis 1

Using an alternative (XM) screening method will significantly improve the apparent quality of halftone reproduction when compared to conventional screening method reproduced on coated paper using an offset lithographic press.

Research Hypothesis 2

Using an alternative (XM) screening method will significantly change the measured values, (i.e. Lab values, Delta E, dot gain, and print contrast) when compared to conventional screening method reproduced on coated paper using an offset lithographic press.

Definitions

Basic density/Screen range—The copy density range that a halftone screen will reproduce (with halftone dots) with a single white light exposure. (Dupont)

Blanket—A rubber-covered sheet used on the blanket cylinder of a lithographic or letterset press that transfers the inked image from the plate to the substrate. (Dennis, Jenkins, 1991)

Coated paper—Paper coated with clay, white pigments, and a binder. (GRACoL, 2001)

Computer to Plate (CTP)—The exposure of a printing plate by a computer-controlled laser, eliminating the need for film. (Cost, 1997)

Continuous tone—Image created from many different tones or shades and reproduced through photography. (Adams, Faux, and Reiber, 1988)

Conventional screening— A pattern of dots of different sizes used to simulate a continuous tone photograph. (Agfa, 1993)

Copy density range—The density difference between the highlights and shadows of the original. (Dupont)

Density—The degree of opacity of a photographic image on paper or film. (Agfa, 1993)

Direct to Plate/Press/Cylinder—The downloading of fully imposed digital forms from a RIP directly to the plate cylinder on the press. (Cost, 1997)

Dot area—The apparent size of a printed dot in relation to the substrate. Generally described as a percentage of substrate covered with ink.

Dot gain or Tonal Value Increase—A printing phenomenon in which dots print larger (mechanical) or appear larger (optical) than intended.

(Leininger, J. 2002)

Dynamic range—The range of tones from lightest to darkest that a scanner can resolve. (GRACoL, 2001)

Halftone—A binary approximation of a continuous-tone image that enables the press to reproduce it using ink spots of equal density arranged in patterns. (GRACoL, 2001)

Halftone/Contact Screen— A prepared piece of film placed between the continuous tone copy and the film when exposing the film to break the continuous tone image into dots of varying sizes and shapes. (Adams, Faux, Reiber, 1988)

Highlights—The lightest areas of an image. (Agfa, 1993)

Hybrid screening—A screening technique that prints with stochastic and conventional screening in the same halftone.

Imagesetter—A computer controlled device used to output images at high resolution onto photographic paper or film.

Lithographic printing plate—Typically, a sheet of aluminum with a predetermined uniform thickness that has a photopolymer emulsion applied to create the image area when exposed to UV light.

Offset lithography—A printing method that uses the repellent properties of oil and water to reproduce an image on a flat surface that contains both the image and non-image areas. (GRACoL, 2001)

Process Camera—Device used to make enlargements, reductions, and same size reproductions of originals for use in page composition or stripping work. The camera may be used to produce a film negative, film positive, or a print. (Prust, 1999).

Shadows—Darker parts of a continuous tone image or its halftone reproduction. (Adams, Faux, and Reiber, 1988)

Spectrophotometer—An instrument that measures the visible color wavelength from 380 nanometers to 720 nanometers in five to twenty nanometer increments. (Bohnen, O'Leary).

Stochastic screening—An alternative to conventional screening that divides an image into very fine randomly placed microdots, rather than a grid of halftone cells. (Agfa, 1993)

Sublima screening—A hybrid screening technique developed by Agfa which prints stochastic dots in the highlights and shadows and conventional dots in the midtones of the halftone.

Uncoated paper—Raw interlocking cellulose fibers formed into a sheet. (Adams, Faux, and Reiber, 1988)

Limitations

Limitations of this study include three areas; the known physical limitations of comparing screening methods utilized in lithographic printing, the unknown possibilities related to invention, and the psychological affect of a study involving people choosing one method as better than another.

A physical limitation of this study of this study is the comparison of one conventional and two alternative screening methods from the same family. Both alternative screenings are hybrid screenings (a combination of AM and FM). This causes problems in counting the number of selections attributed to the alternative screening. The data would have been clearer if two XM and two AM screenings were used. Another limitation is the use of only one printing process. Other processes could reveal higher quality if the alternative method were used. Others include the few number of reproduction processes and presses used, the lack of standardized viewing conditions, and the attempt to quantify a subjective evaluation in determining apparent quality.

The unknown possibilities are limitless when deciding whether to continue or halt invention and testing of new ideas. At what point do printers stop investing in technology that will produce “higher quality” lithographic printing? What is acceptable quality? Should printers and software developers continue to invest time, energy, and funds to increase the quality beyond present capabilities to a point where the only person that can tell the difference is the print buyer with the 100 X power loupe? If so, should these developers invest time and energy in changing the structure of the dot? Is there some new technology that would launch from current technology to produce better than photo quality and set a new standard of expectation? Should printing craftsmen concentrate in different areas for improvement or should they continue to invest in the apparent quality of the halftone? This researcher recognizes these questions cannot fully be answered by this study. Only time and continued research will indicate whether research and development teams should have stopped trying to improve the appearance of the halftone or be thankful that someone persevered.

A distinct limitation of this study is the psychology of the participants in that each seemed compelled to find a difference. When the participants were given the instructions for the evaluation of the printed halftones, they wanted to know what they were looking for that was different. They assumed there was a difference before looking at the printed samples.

Summary

Printers are still concerned with craftsmanship and are always looking for means to produce faster jobs with improved quality. The invention of new halftone screening techniques is one of the methods imaging companies have developed to aid in the improvement of the quality of the printed piece. An alternative screen method developed by Agfa, is one of the newer methods of screening that incorporates both AM and FM screening. This study was an attempt to determine if the apparent quality of the halftone was improved by the utilization of the alternative (XM) screening.

CHAPTER 2

REVIEW OF LITERATURE

Background

Graphic communication's purpose is communicating through pictures and words to inform, entice, sell, persuade, entertain, educate, and get attention. (Adams, Faux, and Rieber) Everywhere we look, we are barraged with the many forms this takes. From books and magazines to point of purchase displays, floor tiles, clothing, sheets, bumper stickers, and food labels, graphic communication is an often taken-for-granted segment of our society. With the invention of the printing press, all of these communication opportunities have become available to the general public.

It has been said that a picture is worth a thousand words so printers have worked to develop effective and efficient means of including pictures in their publications since the early days of printing. In these early days, craftsmen tried to simulate tonal variation by placing lines, etched or engraved into wood or copper, close together. (Heidelberg News) Currently, commercial printing processes do not print with the number of varying shades of gray to produce the tonal gradation of a true continuous tone seen in black and white photography, so printers use dots of varying size and/or frequency to trick the eye into seeing different tones. The light reflected from the substrate is absorbed with a larger dot/more dots and looks darker. When a smaller dot or fewer dots are printed, the area looks lighter because more like is reflected. When the resolution is high enough, the human eye cannot distinguish the dots; therefore, all the eye perceives is tonal difference.

Significance/Purpose of the Study

The purpose of this study is to determine if significant improvements are being made in halftone reproduction by utilizing an alternative screening (XM) method when compared to a conventional (AM) screening in commercial offset lithography. The data collected will assist printers make a more informed decision when asked to invest in alternative screenings.

Printing Processes

There are five main processes used in the production of printed pieces and some graphic design work is moving into the area of web design for the Internet. The five areas are screen printing/serigraphy, lithography/planographic, gravure/intaglio, flexography/relief, and non-impact methods like digital and inkjet.

Each one of these processes has a niche market depending on the end use and the substrate (object to be printed). Otherwise, everything could be printed by one method. Is the product going to be displayed inside or outside? Will it be in sheets or on a roll? How many copies do we need? These factors must be considered when choosing the appropriate process.

Gravure/Intaglio

The gravure image carrier utilizes cells or wells etched into a copper cylinder which comprise the image area and the non-image area is the smooth non etched surface of the cylinder (Bruno, 1997). This cylinder is electromechanically engraved by computer controlled engraving heads. The cylinder rotates in a bath of ink. The ink fills the cells and a doctor blade scrapes the excess ink off of the non-image area. The substrate passes between the plate cylinder and the impression cylinder which allows capillary action to pull the ink onto it thereby creating the printed piece (See Figure 2.1)

Gravure is considered to be the highest quality halftone printing available for low quality substrates and is used for extremely long runs of high end magazines because of the durability of the image carrier. Many monthly and weekly periodicals are printed via the gravure process. It is very fast once the press is running and color matching, even on different presses in different parts of the country, is possible because the ink film thickness is not varied during the run.

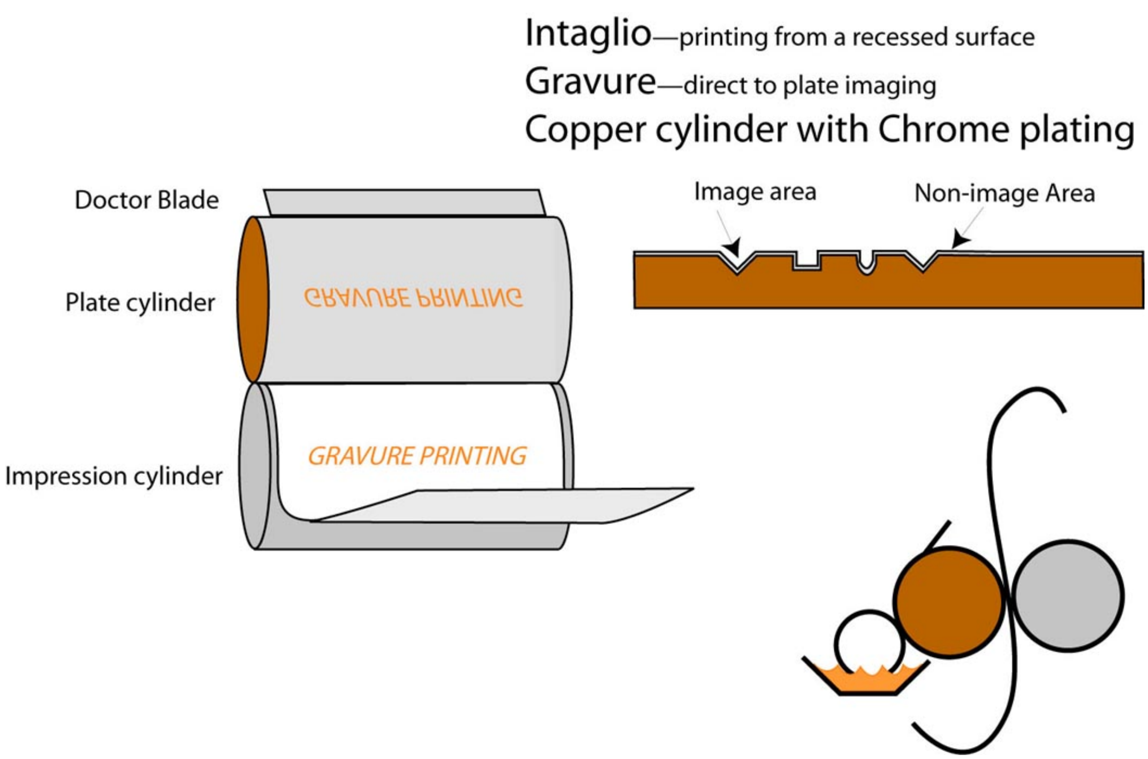


Figure 2.1—Schematic of a gravure printing press

Screen Printing

Screen printing utilizes a porous screen mesh made of fine silk, polyester, nylon, dacron, or stainless steel stretched over a frame (Bruno, 1997) The image area is created with a photographic emulsion which is adhered to the mesh and exposed by a film positive. The exposed emulsion hardens and the unexposed emulsion is washed away with warm water. This creates a stencil, which is put onto a screen press. Ink is placed on top of the screen and a rubber squeegee is pulled across the screen pushing the ink through the open holes in the mesh and onto the substrate. (See Figure 2.2)

Screen printing is considered to be the slowest printing process but is the only one that can deliver substantial ink film thickness. Large point of purchase displays and fine art works are printed by screen printing. The variety of substrates is overwhelming. Screens can print cups, hats, shirts, sheets, corrugated, the films on the sides of buses, paper, the keys on a telephone, and notebook covers. The list is virtually endless. The introduction of rotary screen printing has allowed for faster run speeds as a result of continuous operation. (Rose, 2000)

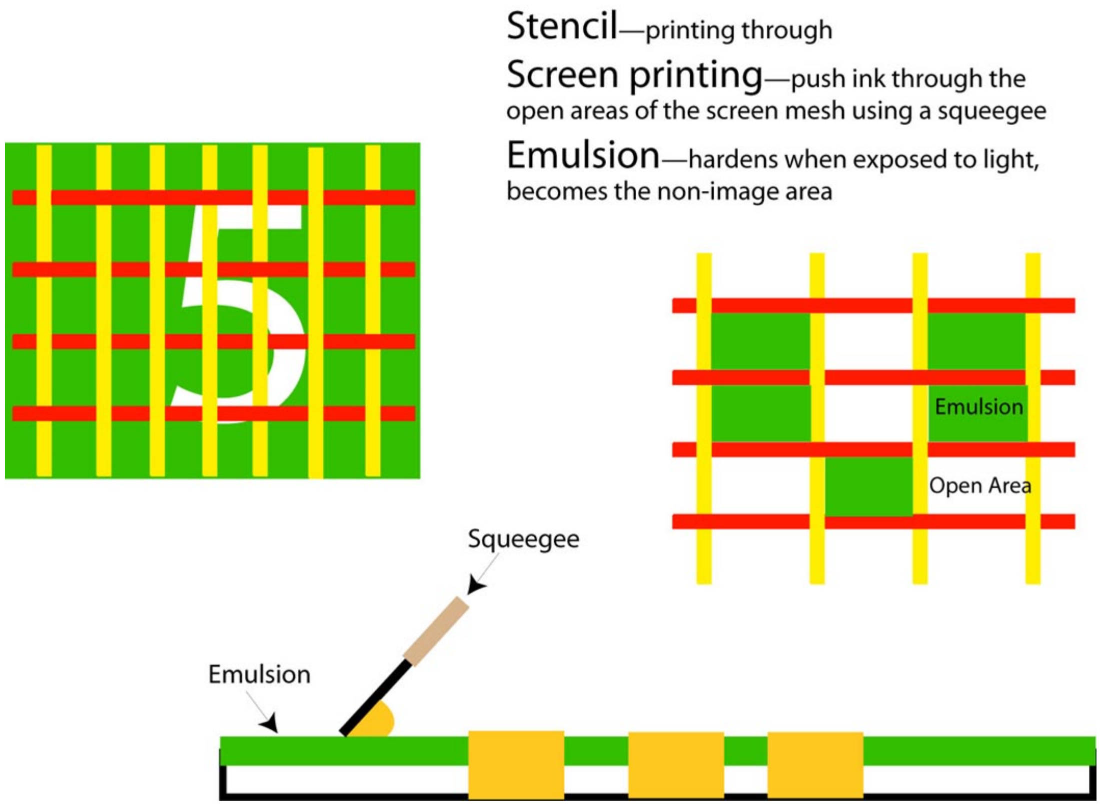


Figure 2.2—Schematic of screen printing system

Flexography/Relief Printing

Flexography is a form of web-fed relief printing which uses flexible rubber or resilient photopolymer relief plates and fast drying, low viscosity solvent, water-based, or UV inks delivered by an anilox inking system (Bruno, 1997). The image carrier is placed on a cylinder that can vary in circumference to produce varying repeat lengths. This image area is inked by the anilox roller, similar to a gravure cylinder, and is pressed against the substrate with a “kiss” impression. Capillary action pulls the ink out of the anilox, which transfers it to the plate. The impression between the plate and the impression cylinder transfers the ink to the substrate (See Figure 2.3).

The flexographic process is known for printing tags, labels, chip bags, decals, and post cards. The press can turn the substrate over with a turn bar and print on the back side. You can economically add print stations and print several spot colors on a substrate that will later be converted into a food container. (Snyder, 2001) The speed and ease of adding finishing operations, like sheeting, slitting, scoring, and die cutting, make flexography an effective choice for the above uses. New screening techniques, like Sublima are continuing to improve the quality of halftones printed by this method (Ingram, 2003).

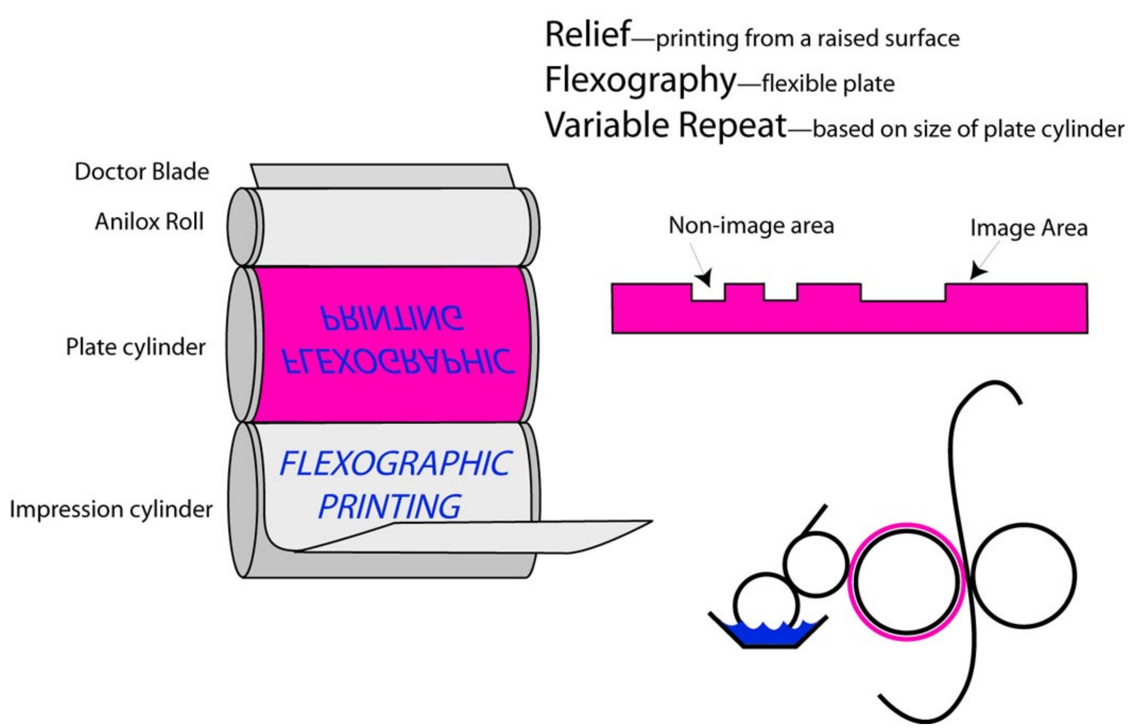


Figure 2.3—Schematic of a flexographic printing press

Offset Lithography/Planographic

Lithography is still the most used printing process. The image carrier/plate is planographic or flat. (See Figure 2.4) The plate is wrapped around the plate cylinder, wet with fountain solution, and inked by the form rollers. The image area on the plate repels the water and therefore allows the ink to stick. The image is then offset to the rubber blanket. When the substrate passes between the blanket and impression cylinder, the image is pressed onto it, thereby creating the printed piece (Prust, 1999). The press operators can print on a web or sheet-fed press. He/she can print on both sides of the sheet with one pass through the press. The quality of lithography is fantastic. Nice crisp edges are a characteristic of litho printing. A variety of press configurations offer short (500 sheets) to long run (1,000,000 sheets) capability while remaining cost effective. (Leininger, 2000) One of the problems with sheet fed lithography is the lack of finishing operations that can be installed on the end. Web fed lithographic presses have cutters and folders attached, but most other finishing operations are done off line in the bindery. Make-readies are long and costly for most conventional presses, but with computer to plate technology and automatic plate hangers, press make-readies are getting much shorter.

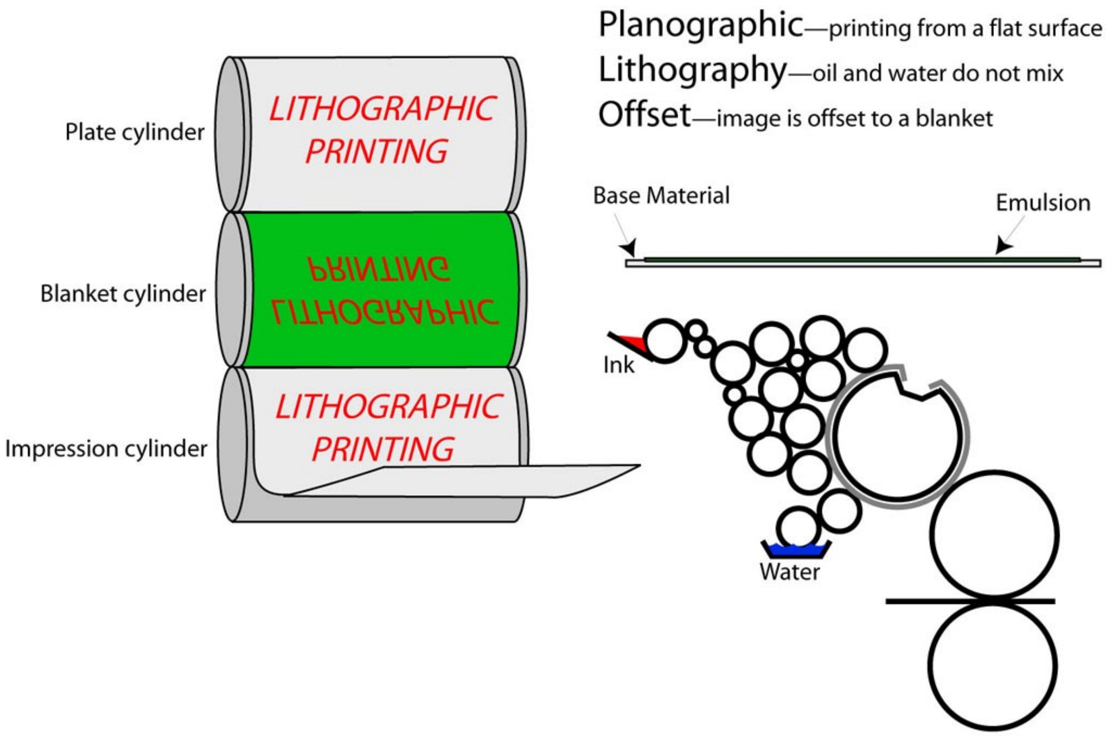


Figure 2.4—Schematic of a lithographic printing press

Digital/Non-Impact Printing (NIP)

Electrophotography, Ionography, Magnetography, Ink Jet, Thermography, Photography, “X”-ography are some of the methods used in non-impact printing. The most widely used are electrophotography and inkjet printing. (Kipphan, 2001)

Electrophotography

Electrophotography is the most used non-impact printing technology. (Kipphan, 2001) It is based on an invention by Chester Carlson, patented in 1942. The schematic for electrophotography is shown in Figure 2.5.1

The process of electrophotographic printing can be subdivided into 5 stages:

1. Imaging—a photoconductive surface is charged and is subsequently imaged by a light source usually a laser or LED array. Where the light strikes, a latent image is created which corresponds to the original.

2. Inking—powder or liquid toners are used in the developing unit which transfer to the negatively charged areas corresponding to the latent image on the drum or belt.

3. Toner transfer (printing)—toner is usually transferred from the drum or belt to the substrate. An electrostatic (corona charge) and pressure assists in the transfer at the printing nip.

4. Toner fixing/fusing—a heated unit then melts the toner and presses it onto the substrate.

5. Cleaning (conditioning)—after the toner is transferred to the substrate, residual toner remains and must be removed. This is typically done with mechanical and electrical means. A brush and/or vacuum are used to mechanically remove remaining particles and a neutralizing electrical charge is emitted to condition and prepare the drum/belt for the next image. (Kipphan, 2001)

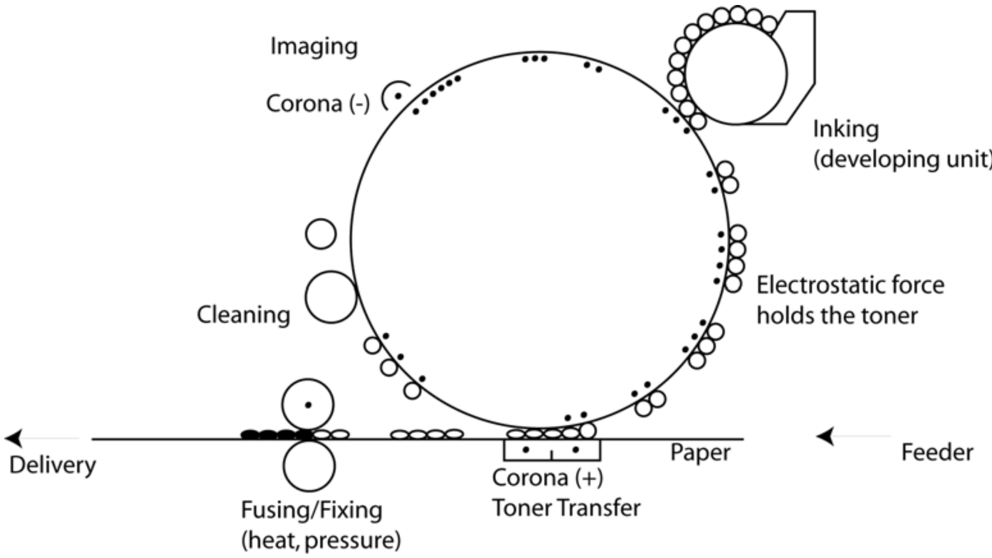


Figure 2.5.1—Basic Schematic of Electrophotography.
Adapted from the *Handbook of Print Media.*

Ink Jet Printing

Another very common NIP process is ink jet. Ink is sprayed directly onto the substrate requiring no image carrier. Two general systems are used to deliver ink to the substrate; continuous ink jet and drop on demand ink jet. Liquid inks are commonly used with some drop on demand systems using hot-melt inks. When liquid inks are used, very thin ink films can be applied to the substrate. Extremely high quality multicolor ink jet prints can be created by using coated papers that prevent ink absorption and spread, also called dot gain, from occurring. (Kipphan, 2001)

Continuous Ink Jet

With continuous ink jet systems, the ink is delivered in a continuous stream of liquid ink drops. In the image areas, the drops are allowed to reach the substrate while in the non image area they are deflected and sent to a gutter for recirculation back into the delivery system as shown in Figure 2.5.2.

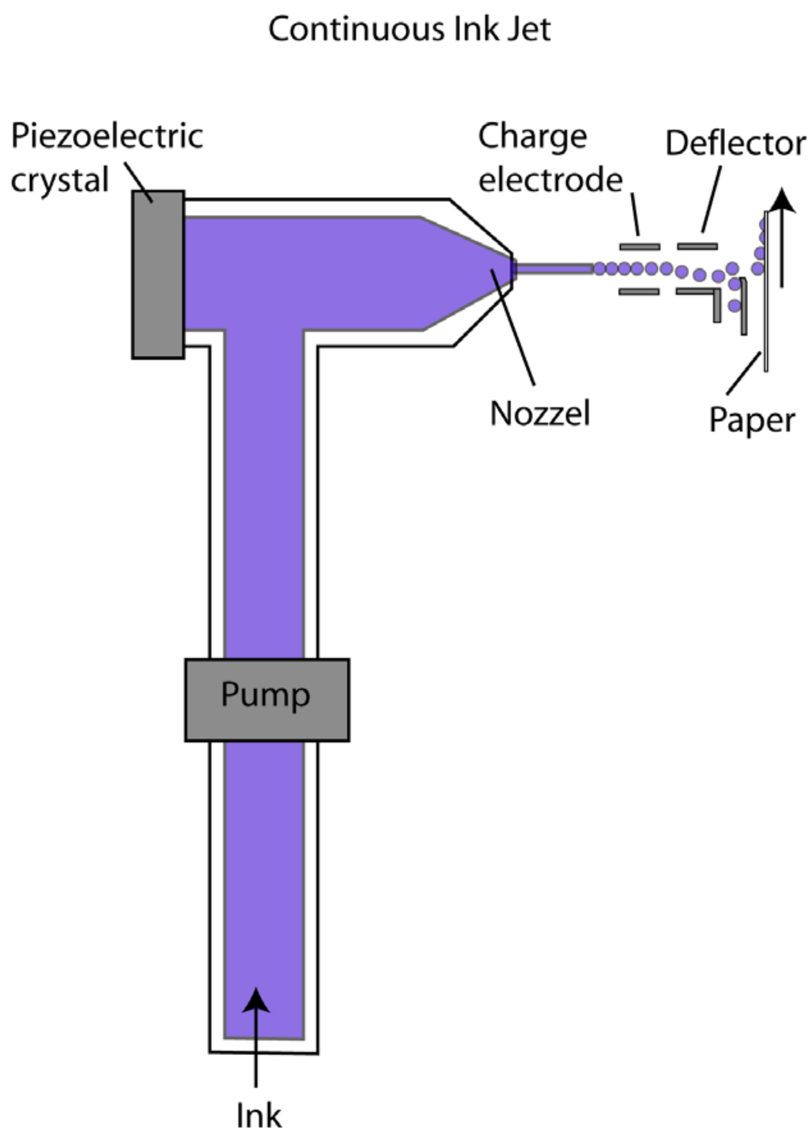


Figure 2.5.2—Schematic of Continuous Ink Jet System
Adapted from the *Handbook of Print Media*

Drop on Demand

Although most drop on demand ink jet systems use liquid inks, the system differs from a continuous ink jet system in that ink is delivered only when the digital signal, corresponding to the image area, is emitted. Three types of drop on demand systems are; thermal/bubble jet, piezo ink jet, and electrostatic ink jet. The individual classification of drop on demand processes is related to the way the drop is generated as shown in Figure 2.5.3.

Thermal ink systems heat the ink creating a vapor bubble. When the bubble grows large enough, it creates pressure and the ink is ejected from the nozzle.

In a piezoelectric system, the piezoelectric ceramic is deformed which decreases the volume within the ink chamber. Ink is then ejected through the nozzle.

An electrical field is generated within the electrostatic ink jet system. This field withdraws the ink from the nozzle when combined with a control pulse (electrical signal or heat application).

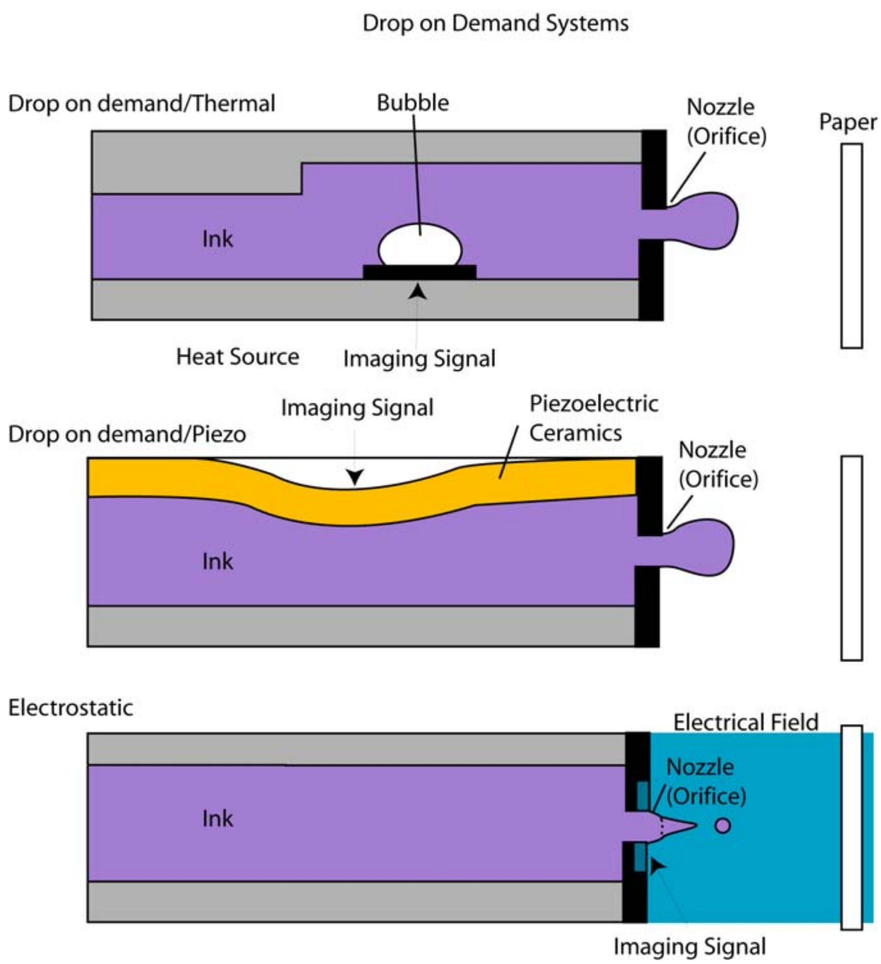


Figure 2.5.3—Schematic for Three Drop on Demand Ink Jet Systems Adapted from the *Handbook of Print Media*

<u>NIP Systems Specifications</u>

Model (manufacturer)	6000 (Xeikon)	Indigo 5500 (HP)	iGen3 110 (Xerox)	ColorSpan 9840 uv (MacDermid)
NIP Processes	Electrophotography Form Adapted Powder toner	Electrophotography Liquid Toner 7C	Electrophotography Benchmark gamut of CMYK dry inks	Ink Jet—Large Format SolaChrome-UV Extended Gamut Pigmented Inks
Printing format substrate	320-508 mm wide Web	13 x 19 inch Sheet	14.3 x 22.5 inch Sheet or Web	6 to 98 inches wide Web
Duplex Printing	Yes/One Pass	Yes/Perfector	Yes	No

Addressability dpi	600	2400 x 2400	600 x 4800	600 x 600
Productivity	9,600 p/hr	4,000 4/0 8.5 x 11 two up p/hr	6,600 4/0 8.5 x 11 1,500 4/4 11 x 17	225 sq. ft/hr in production mode
Quality Control/Specs	▪ In-line densitometer ▪ Front to back Registration Control	▪ In-line densitometer ▪ ILD color adjustment	▪ Built-in intelligence ▪ Automatically adjusts to paper characteristics ▪ Monitors every print ▪ Provides online diagnostics and remote support	▪ Dual High-Intensity UV Lamps provide instant curing of ink printing in both directions ▪ 16 Micro-Quad Piezo Printheads

Figure 2.5.4—Non-Impact Printing (NIP) presses and their specifications

Screening Methods Introduction

Continuous tone to halftone

Conventional, stochastic, amplitude modulated (AM), frequency modulated (FM), dot shape, LPI, and dpi are all terms describing the process of converting a continuous tone (CT) image into a halftone for print. Lay people seldom consider what occurs when they click File>Print. Instead, they simply want images and words that adequately convey their messages. Therefore, the processes their computers and printers use to convert halftones are of little or no concern. On the other hand, to remain competitive, printers are engaged in a never-ending quest to increase the aesthetic qualities and fidelity of printed reproductions. Since halftoning techniques strongly impact the appearance of printed reproductions, printing companies must carefully choose and implement the most appropriate conversion processes available.

The introduction of computers into the printing process drastically changed the way the CT to halftone conversion occurs. Computers provided, at minimum, two things: 1) a simplification of the CT to halftone conversion process and 2) more precise control over the resultant image. Anyone who used a conventional process camera to make a halftone, used a Kodak® Q-15 Halftone Calculator, or dot etched a negative knows this to be true.

Improved technology increases expectations. Both print buyers and employers of print technicians demand the increased quality and fidelity afforded by new halftoning technologies.

How halftoning creates tonal difference

Tonal difference, shades of gray, and detail are interrelated terms used to explain a different shade or tint in one area of a photograph compared to that in another area. Figure 2.6 is a halftone reproduction of an original CT photograph that contained tonal differences (shades of gray) across the image. Without the detail resulting from these shades of gray, there would be no image. The image created by the varying shades of gray in the halftone in Figure 2.6 is an illusion: the differences in tone are caused by dots of different size or frequency rather than by varying shades of black and white. A press either prints ink or leaves the substrate blank. When large-sized or a large number of halftone dots cover the substrate (paper), they absorb the reflected light and darken the page. Conversely, wherever there are small or few dots, light is reflected to the viewer so that the page appears light. To create detail, the total coverage of ink in a given area must be different than that in a neighboring area.

Figure 2.6 —Tonal differences in halftones are an illusion.

Screening Processes Defined

Halftones are created using three different techniques: conventional (AM), stochastic (FM), and hybrid. Each of these techniques can be used to create the illusion of shades of gray, but many times one screening method may be better utilized than another. “The screening technique should enhance the image for the printing process…a particular screening technique may enhance the ability to reproduce the image satisfactorily.” (Ingram, 1994)

Conventional (AM) screening

Conventional, or amplitude modulated (AM) screening, was patented by William Henry Fox Talbot in 1852. It uses varying-sized dots on a crisscross pattern similar to graph paper or grids in Adobe Photoshop®. As shown in Figure 2.7, the size of the dots in the grid pattern controls the intensity of the light reflected back from the substrate. In a highlight area of a halftone, small dots of ink absorb a small amount of light while allowing most of the light to reflect. Conversely, in shadow areas, larger dots absorb more light so that very little light can reflect from the substrate. The viewer sees only the light that is reflected. Therefore, small dots result in light areas while large dots result in darker areas. The dots, if small enough, cannot be readily perceived by humans due to the poor ability of our eyes to resolve them.

AM screening, which has both positive and negative characteristics, has been the primary method of halftone conversion for over 100 years. On the positive side, AM screening provides a particularly smooth transition from one mid-tone dot size to another. In addition, AM screening provides superior results when printing screen tints. However, AM highlight dots are sometimes so small that they disappear (drop) during the production cycle. At the dark end of the tonal scale, AM dots are very large, overlapped, and separated by very small unprinted areas. Human error in platemaking or the application of too much pressure or ink during the press run often causes the dots to grow so large that the small unprinted areas disappear (fill in). These phenomena at both ends of the tonal scale equate to diminished highlight and shadow detail. Therefore, the conversion process has to be carefully managed to minimize unexpected changes in the dot structure. George Leyda, retired from the printing industry, has suggested a system; PASOCCI—Prepare, Analyze, Stabilize, Optimize, Calibrate, Characterize, and Implement. The activities involved with PASOCCI provide a model for technology implementation in which the conversion system must be calibrated to maintain a consistent output from known inputs. Once this is managed, the system can be characterized to determine the expected output from the calibrated inputs.

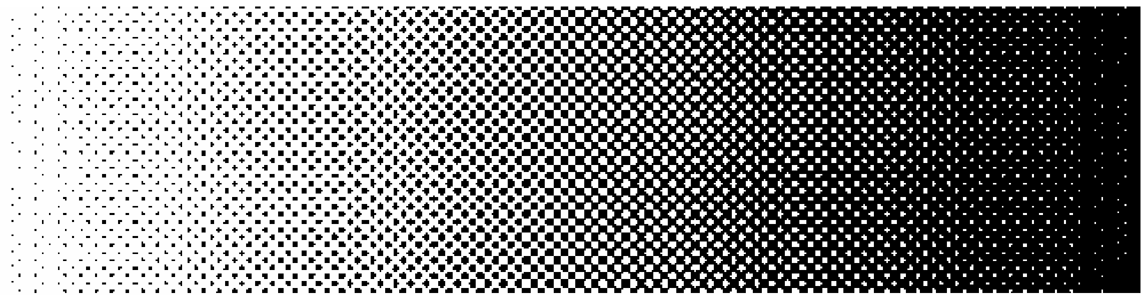


Figure 2.7—A range of tones reproduced using enlarged AM halftone dots

Stochastic (FM) screening

Stochastic screening, also known as frequency modulated (FM) screening, was invented in 1965 by Karl Scheuter at Technical University of Darmstadt in West Germany. Not until three decades later did computing power, PostScript interpreters, and image- and platesetters become robust enough to allow Scheuter's invention to be implemented (Bridg's, 2004). When FM screening is employed, the number (frequency) of dots, rather than dot size, controls the amount of the light reflected from the substrate (see Figure 2.8). In a highlight area of a halftone, a few same-sized dots absorb very little of the light. Therefore, most of the light is reflected. In shadow areas, a greater frequency of dots absorbs more light, causing very little light to reflect from the substrate. As light is absorbed or reflected throughout the halftone, detail is produced by the varying frequency of dots.

If properly employed, FM screening techniques can increase the aesthetic qualities and fidelity of reproductions. Advocates of FM screening would say that FM techniques provide increased image detail due to smaller FM dots. In addition, the FM screening process eliminates moiré—an objectionable pattern caused by the overlapped angles inherent in AM screening. In particular, FM technologies allow printers to effectively print hi-fidelity color reproductions in six or more colors. Additional colors dramatically increase the color gamut of printed images.

If the press is properly controlled and if the substrate is a smooth coated stock, FM highlight dots do not disappear and shadow dots do not plug because all of the dots are the same size. On the other hand, if too much fountain solution is used on a lithographic press, the fine microdots in the highlights can be easily lost due to over flooding of the small oleophilic areas of the plate. Similarly, if a rough uncoated paper is used, the microdots can disappear between the fibers. In addition, too much plate-to-blanket or blanket-to-paper pressure can cause micro shadow dots to plug. Thus, FM screening techniques require fine-tuned press operations.

"FM screening is still considered an emerging technology. It entails significant change to the printing mindset and has been subject to a very healthy dose of scrutiny over the years. It is well understood that FM screening eliminates screening moiré, screening rosettes and delivers photographic quality while boosting fidelity and detail in the reproduction of images" (Blondale, 2003).

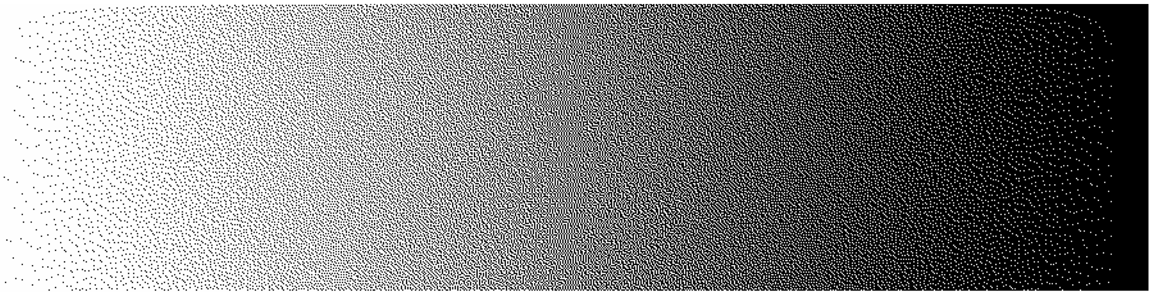


Figure 2.8—A range of tones reproduced using FM halftone dots

<u>Hybrid screening</u>

Hybrid screening is a combination of AM and FM screening that utilizes the best qualities of each. In particular, most hybrid technologies retain the FM rendition of highlight and shadow dots. This allows fine detail provided by random clusters of microdots that are not confined to a grid pattern. On the other hand, AM screening typically provides a smoother transition of tone in the midtones. So, one approach to hybrid screening would be to utilize FM dots in the highlights and shadows while employing AM dots in the midtones.

Two approaches to hybrid screening include Hybrid FM (also known as Second Order FM) and Hybrid AM (also called XM). Hybrid FM screens grow the dot's length or change its shape depending on the screen design.

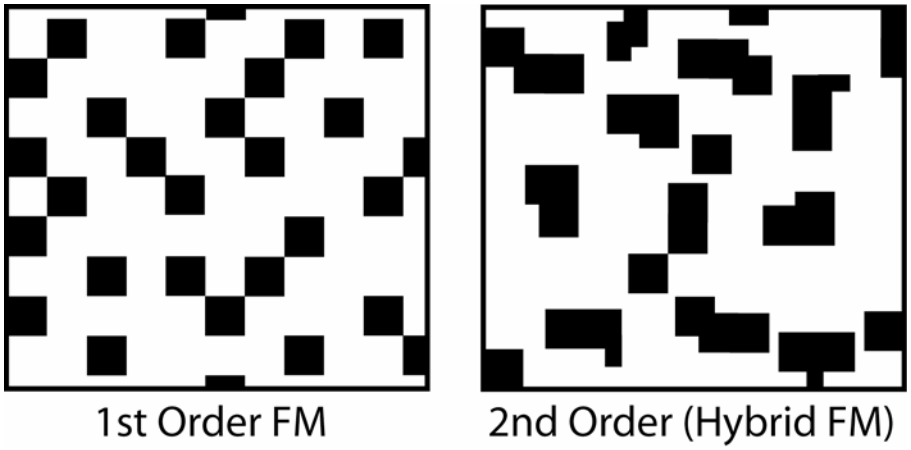


Figure 2.9—Diagram of 1st and 2nd order FM screening

When Hybrid AM is employed, the size of the dots in the highlights and shadows are constrained to the size of the smallest printable dot on a particular press using a given substrate. For example, if the smallest dot a press can hold is a 21-micron dot, Hybrid AM techniques would utilize no dot smaller than 21 microns. To make a lighter area than the 21-micron dot produces, dots are removed from the grid. This prevents dots that are too small from dropping on press, while resulting in a lighter perceived tone. A similar process is employed in the shadows: no dots larger than the largest consistently printable shadow dots are used. To make a darker tone, specific areas are allowed to go solid. The midtones are produced with a conventional (AM) screening technique. Midtone and highlight illustrations are shown in Figure 2.10. Note the missing (smallest printable) dots as the dot percentage decreases, yet the dots remain on a grid at the defined AM angle.

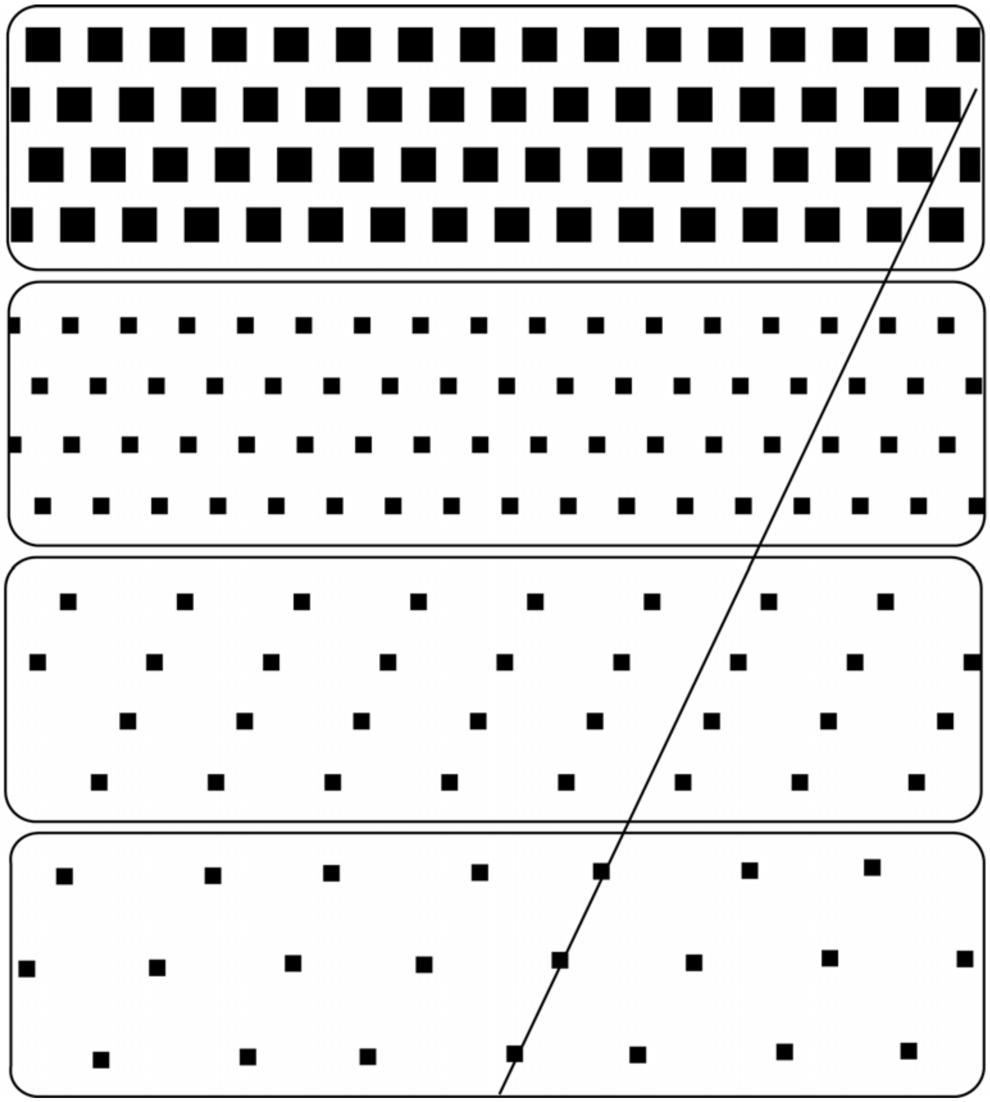


Figure 2.10—Dots have stopped decreasing in size and began decreasing in frequency. Drawing adapted from a Sublima® Brochure developed by Agfa Corp.

Choosing the Appropriate Screening Technique

The placement and structure of dots resulting from any halftoning technique will result in a similar image, especially if the image is viewed from a distance. Changing the halftoning process will result in only minor differences in image quality and tonal range.

Printers who desire to increase the fidelity of printed reproductions may be tempted to implement FM or hybrid screening technologies. Such implementation may produce sharper and richer halftone reproductions. However, these improvements must not be taken at the expense of a smooth and economical workflow. Whenever a halftoning process disrupts workflow—for example, by requiring a specialized raster image processor (RIP) or output device—or adversely affects the pricing of a job, printers would be wise to be prudent in their adoption of new technologies.

Depending on the specific application, each of the three screening technologies explored in this research paper fills a niche based on the process, substrate, and ink used to reproduce the original photograph. When choosing a screening technique, it is important to consider the basics of photographic reproduction rather than get caught up in new technology for new technology's sake.

Back to the Basics

Regardless of screening technique, it is important to remember that all reproductions should faithfully reproduce the intent of the original in light of the circumstances in which the printed image will be viewed. In particular, halftones must accurately control light and provide an appropriate resolution depending on viewing distance.

Controlling light

All halftoning processes create dots that control the light reflected back from the substrate. Considering again that a press either prints ink or leaves the substrate blank, a dot of black ink absorbs the light that strikes it while unprinted paper reflects the light.

Regardless of the arrangement of the dots, the image perceived by the viewer is controlled by the absorption and reflection of light. The different dot structures in Figure 2.11 illustrate that the combination of black dots and white paper display the illusion of gray when viewed at a distance great enough so the human eye can no longer resolve the individual dots.

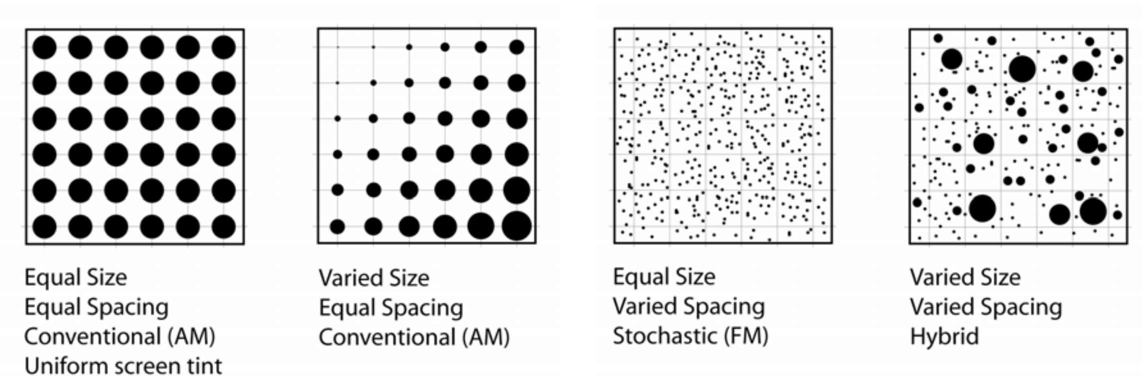


Figure 2.11—All dot structures control light absorption and reflection; (drawing adapted from a similar drawing in *The Handbook of Print Media*)

<u>Viewing Distance</u>

Halftone dots should not be discernable by a reader at the viewing distance appropriate for a given type of reproduced image. Although the perception of individual dots is affected by the viewer's visual acuity, it is also dependent upon the distance between the printed page and the viewer. A photograph in a magazine is generally viewed at a distance between 12 and 20 inches. So, small dots are appropriate. On the other hand, very large dots may be employed on a roadside billboard since viewing distance could be hundreds of feet.

Resolution

The smaller the halftone dots, the less likely they are to be discerned by the viewer. To make dots smaller, increase the number of lines per inch (LPI) so that more lines of dots are displayed. In Figure 2.12, four times the number of dots is required to display the square at 16 LPI in comparison to the square at eight LPI. If the viewing distance is increased so that the 16 LPI dots begin to merge into perceived lines creating a square, the eight LPI dots will still be distinguishable.

The choice of the appropriate LPI for a given job is complex and must consider the image resolution of the original scan or digital photograph, the capabilities of the imagesetter or platesetter, and the chosen printing process, press, ink, and substrate.

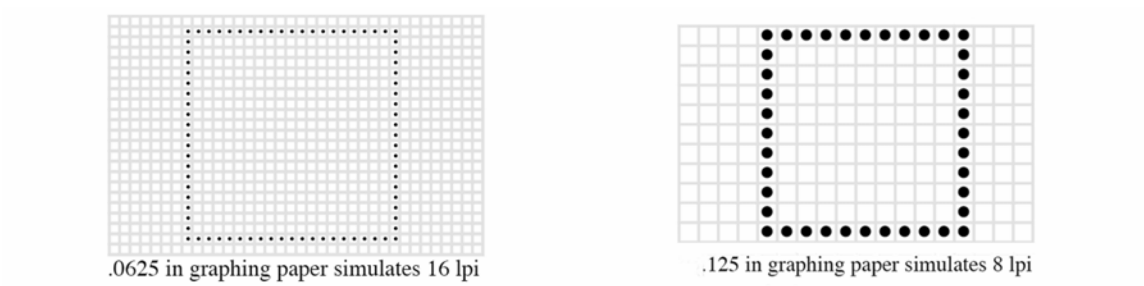


Figure 2.12—When a viewer can no longer distinguish 16 LPI dots, 8 LPI dots can still be discerned

Combining the Basics

Figure 2.13 illustrates a single image reproduced using three different halftone screens. Sample A was originally screened at 20 LPI. Sample B was screened at (150 LPI). Finally, Sample C was originally screened at 40 LPI. In a small test, the researcher had several people view the original version of Figure 2.13 at varying distances. At normal reading distance (between 12 and 20 inches), none of the viewers could discern the halftone dots in Sample B. However, they could all distinguish the individual dots in Samples A and C. If five–seven feet separated the viewer and Figure 2.13, depending upon the visual acuity of the individual, Samples B and C appeared the same. Thus, at a distance of five–seven feet, 40 LPI dots seem to disappear. When the viewers moved back to a distance of 10–13 feet, Samples A, B, and C all appeared the same because, at that distance, 20 LPI dots seem to disappear. Therefore, the greater the viewing distance, the lower the LPI can be without affecting the visual quality of the reproduction.

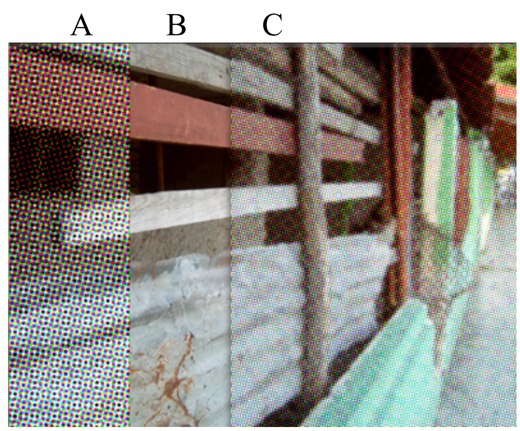


Figure 2.13—The different LPI dots in this composite image disappear at varying viewing distances

What is Quality?

Webster's Dictionary

Quality is denoted in *Webster's Dictionary Online (*http://www.m-w.com/dictionary/quality) as "degree of excellence; superiority in kind". Printers have defined quality simply as "whatever the customer wants and is willing to pay for".

Helmut Kipphan

Helmut Kipphan in *The Handbook of Print Media*, suggests, “A product’s quality is usually defined in terms of its suitability for the anticipated purpose. It would be unwise to conclude from this that a printed product’s quality level could be geared to the requirements of the average end-user. The single decisive factor is the product’s suitability in the client’s eyes. However, the client’s idea of quality usually lies far above what the end-user expects or could even perceive.”

Dr. W. Edwards Deming

“Quality is, as eloquently defined by business management guru Dr. W. Edwards Deming, ‘meeting customer expectations.’ Therefore, a true ‘quality’ printer is one that understands that it is not a question of high or low quality, but rather how closely they have met the expectations of their customers. The ability to efficiently tune a standardized manufacturing platform to meet these custom expectations becomes a cost-efficient competitive differentiator.” (bluelinemedia.com)

Kenly and Beach

Eric Kenly and Mark Beach in *Getting it Printed* have determined five levels of quality: “Do-it-Yourself (DIY) Printing” which involves the use of low cost digital printers. The level of quality is acceptable for internal consumption and is highly variable, but is so widely used and accepted that it should be considered in a discussion of quality levels. “Basic Printing” involves standard materials and quality control at quick printers and copy centers utilizing toner based machines in one or two colors. “Good Printing” involves standard materials and quality control at commercial and publications printers with tight register/not perfect. Examples could include magazines such as *Time* and *Newsweek.* "Premium Printing" requires careful attention to detail, high grade materials and presses using ink or toner with few flaws. This level of printing would seem almost perfect to non-graphics professionals. Examples could include upscale clothing catalogues, annual reports, or high end periodicals like *National Geographic.* "Showcase Printing" combines the best machines and materials with operators who give scrupulous attention to detail. Everything from design to paper is first class. This level of printing will offer as close as possible color matches. Examples could include museum grade art books, brochures for expensive automobiles and resorts, and the finest annual reports.

<u>HPMA (Houston Print Managers Association) Pilot Study</u>

As part of the pilot study for this experiment, subjective words were determined during a presentation to the HPMA (Houston Print Managers Association) to denote quality of a printed reproduction. Those words are as follows:

- Sharpness—Clarity and focus of the photo. The sharper the picture, the more crisp it looks. The less sharpness in the picture would show a softer focus. Don't be confused with selective focus as in the picture of the Iguana. There are parts of that photo that are supposed to be out of focus.
- Color Balance—The colors look like they are supposed to look. Greens are green, blues are blue, etc.

- Detail—The difference in tone that provide the shapes, curves, shadows, and tiny significant parts of the photo. Detail allows you to see these subtle differences in the picture.
- Contrast—The difference between the dark and the light areas of the photo that provide the subtle changes in tone. These slight changes provide the detail that keeps the picture from looking like one big blob of ink.
- Saturation—The intensity or vibrancy of the color represented. The more saturated the color, the further away it is from gray. The less saturated, the closer it is to gray or white.

Summary

For more than 150 years, printers have been faithfully reproducing CT originals using halftoning techniques. For about 120 years, printers could only use the AM halftoning technique invented in the 1800s by Henry Talbot. In recent years, the advent of powerful RIPs and high- resolution output devices has increased the variety of halftoning techniques available to the printer. In particular, FM and Hybrid techniques can be used to increase the aesthetic qualities and fidelity of printed reproductions. Each of these new techniques provides benefits and drawbacks as highlighted in this paper. Printers and students of printing need to test these techniques to ensure that their benefits outweigh their costs. "The screening technique must be analyzed with respect for its reproduction characteristics…production means film, proof, plate and printed image." (Ingram, 1994)

CHAPTER 3

METHODOLOGY

Significance/Purpose of the Study

The purpose of this study is to determine if significant improvements can be made in halftone reproduction by utilizing an alternative screening (XM) method when compared to a conventional (AM) screening in commercial offset lithography. The data from this independent comparative analysis will enable printers to make a more informed decision when considering an investment in an alternative screening method.

Setting of the Study

This experimental study was conducted at two locations in Houston, Texas. One of the locations was in a University Graphic Communications Laboratory and will henceforth be called the University Lab. The other was in a large commercial printing facility and will be called the Printer.

The evaluation of the printed images was conducted in a variety of settings across the United States. An accounting of these locations is tabled in Appendix D.

Population/Sample of Press Sheets and Evaluators

Sample of Press Sheets

A press run of 400 sheets was completed by the Printer. The procedures for the press run are listed in "Procedures for Sample Reproduction". A random sample of 100 press sheets were cut into individual rectangles, strips, and squares; dividing the prints, tone scales, tint patches, and press targets. Those were labeled and wrapped as outlined in "Subjective Evaluation of the Apparent Quality of the Halftones".

Participants Evaluating the Printed Samples

One hundred forty participants were selected to evaluate the prints. The participants have varying degrees of knowledge and experience in printing. The participants were separated into two groups; those with printing experience and those with limited printing experience. Press operators, estimators, sales and customer service representatives, print buyers and graphic communications instructors with extensive knowledge of apparent quality and press operations characterized the first group. High school teachers and others with limited printing experience, representing the average layperson, comprised the second group.

Prepress Procedure

The press used at the Printer was a Heidelberg Speedmaster 102-6-P3. The press sheet was designed so the test images fit on a 28 x 40 inch press sheet, as shown in Appendix G. The test images include one and four color halftones and tone scales with conventional ABS (Agfa Balanced screening) at 200 lpi and the alternative (XM) at 340 lpi, and the alternative (XM) at 240 lpi. The plates for the press runs were exposed on an Agfa Galileo 8 VS platesetter and processed at Agfa in New Jersey.

Procedures for Sample Reproduction

The pressrun was completed by the Printer using cyan, magenta, yellow, and black ink in keeping with normal press operations. The substrate is coated paper. The specifics of the print production run are as follows:

Plates: Agfa Azora

Ink: Toyo MZ, CMYK

Fountain Solution: Prisco 3451-U

Paper: Unisource 80# Cover

Press: Heidelberg Speedmaster 102-6-P3

Rollers: Bottchere

Powder: Oxy-Dry #744

Target solid ink density with acceptable tolerance of +/- .05

K=1.75	M=1.4
C=1.35	Y=.92

Design

This research was of an experimental design including one control group in which the experimental screening technology was compared to the control. The control was conventional and the experimental was two different line rulings of the alternative (XM) screening. The apparent quality of the alternative (XM) screening was compared in two ways: visually and through measurement using a spectrophotometer.

Instrumentation

The evaluation of the apparent quality of the halftones was measured using a survey shown in Appendix C. This survey includes demographic data about the evaluator and a section for the selection of the highest quality of reproduction.

Subjective Evaluation of the Apparent Quality of the Halftones

During a planning session for the flexographic/Sublima project, Dr. Page Crouch said, “It doesn’t matter what the tone scales measure if the photos don’t look good.” Therefore, the perception of the apparent quality of halftones was determined by having various people evaluate the photos. The people evaluating and selecting the best quality halftones were from two groups; those who know printing and those who do not know printing. They rank ordered the selections utilizing criteria established for the quality of halftones described in “Quality of Halftones” in chapter two of this dissertation. The descriptors and definitions of quality were delivered to the participants as a part of the evaluation survey shown in Appendix F.

The order of viewing of the printed halftones was consistent for everyone who evaluated the halftones. The arrangement of the halftone groupings was randomized as shown in the table below. The screening types are listed as A, B, or C and the viewing order is listed as 1, 2, or 3. The name of the halftone corresponds with what is in the picture.

Screening

A-Conventional (AM) at 200 lpi

B-Alternative (XM) at 340

C-Alternative (XM) at 240

Table 3.1: Viewing Order

Photo		**Screening**		**Viewing Order**
Iguana		B A C		1 2 3
Cougar		C B A		1 2 3
Leaf		A C B		1 2 3
Spools		A B C		1 2 3
Hallway		C A B		1 2 3

Figure 3.1—The viewing order was printed onto a label and the label was adhered to the individual printed halftone.

Figure 3.2—The printed halftones were then stacked in the order of viewing.

Figure 3.3—The halftones were then rubber banded to maintain the order for distribution to the participants evaluating the pieces.

Data Collection

Collecting Survey Data from the Evaluators

The survey in Appendix C was used to gather demographic data as it relates to perceived quality of the prints. The demographic data is on one side of the page and the evaluation of the halftones on the other. The participants were given packets which contained the five sets of printed halftones, the participation letter (Appendix A), the survey instrument (Appendix C), the definitions (Appendix F), and the evaluation instructions (Appendix E). The participants followed the evaluation instructions and completed the survey. They re-banded the prints and turned them in with their survey.

Reading Tone Scales and Tint Patches

The density, dot area, dot gain, and print contrast measurements were completed in the University Lab using an X-Rite 518 Spectrodensitometer. The tone scales were also measured in the University Lab using an X-Rite DTP 22 spectrophotometer connected to a MacPro computer running Colorshop X; version 1.3 software. Colorshop has a Delta calculator feature which allows spectral measurements to be collected into a Color Scratchpad.

This data was then exported and inserted into a Microsoft Excel spreadsheet. It was sorted, graphed, and analyzed with appropriate statistical methods.

Research Hypotheses

Research Hypothesis 1

Using an alternative (XM) screening method will significantly improve the apparent quality of halftone reproduction when compared to conventional screening method reproduced on coated paper using an offset lithographic press.

Research Hypothesis 2

Using an alternative (XM) screening method will significantly change the measured values, (i.e. Lab values, Delta E, dot gain, and print contrast) when compared to conventional screening method reproduced on coated paper using an offset lithographic press.

Reliability

In defining reliability, most would agree that a researcher would attempt to remove as many extraneous and confounding variables as possible in order to get the same result each time the experiment is conducted. Two very different determinates for reliability were studied and implemented in order to ensure the same results each time this experiment would be conducted. One established uniform printing practices that fostered reliable and consistent results. The other created a uniform standard for viewing and evaluating the printed pieces.

Therefore, a print contrast test was performed on the press with tone scales as shown in Appendix G. This was used to establish target solid ink density and as a comparison for a measure of reliability. The test utilizes a solid and an upper middle tone tint, usually seventy-five or eighty percent, as a determinate of the openness of shadow detail. The higher the print contrast, the more "pop" the halftone has. The mathematical formula for this measurement is shown as [the density of the solid minus the density of the tint divided by the density of the solid times 100]. (X-Rite, 2004) For example, if the density of the solid is 1.7 and the density of the tint is 1.2, the problem would be solved as follows. [1.7 – 1.2 = .5 divided by 1.7 = .294 multiplied by 100 = 29.4], which is the number assigned to the print contrast.

In order to establish reliability of the evaluation of the halftones, all participants were given the same quality measures (Appendix F) and evaluated each measure of quality listed on the evaluation sheet in Appendix C. The only change was related to the composition and demographic of the evaluators, and the viewing conditions. These are not controlled outside of the pressroom and therefore simulate actual conditions for normal viewing and evaluation of other printed items.

Validity

In defining validity, most would agree that a researcher is concerned primarily with measuring what he/she sets out to measure. If the research, design and implementation of the study are controlled appropriately, the researcher has documented evidence to support his/her conclusion drawn from analyzing the collected data. In an effort to ensure this research has measured the quality of the printed halftones, two aspects of the study were designed and controlled at the highest level. One is that the printing standards for creating the samples met or exceeded current industry standards for the physical printing of the pieces. The other had to establish an objective evaluation of a subjective measure; quality.

Print contrast is an accepted and objective measure of print quality particularly in the shadows of a halftone. Measuring the tone scales and achieving consistent print contrast measurements can establish validity in determining the optimum printing conditions. Also, following accepted practices outlined in a variety of printing texts and standards publications like GRACol 6 helped to measure and quantify a valid and objective standard of determining quality. The subjective term “Quality” was quantified as objective data and was measured for the results shared in Chapter 4 of this paper.

Summary

This experimental study was conducted to measure the quality of printed halftones that were screened with three different dot structures; conventional ABS, alternative (XM) at 240, and alternative (XM) at 340.

A press sheet was designed by the researcher which was sent to Agfa for plating. The plates were mailed to the researcher and he delivered them to the Printer. The job was run using accepted printing practices and the sheets were cut down.

Packets for the evaluation were constructed containing all the elements necessary to administer the subjective evaluation and complete the survey instrument. (Appendix A-F) This information was then categorized and input for analysis.

The tone scales and tint patches were read with a densitometer and spectrophotometer. The data was entered and analyzed. The results are shared in the following chapter.

CHAPTER 4

RESULTS

Summary of Collected Data

The data collected is from two different areas as outlined in the Methodology section of this research paper; viewing of the printed pieces and tone scales. The viewing of the printed pieces data was analyzed by the demographic information disclosed by each participant; printers and non printers, male and female, and corrected and uncorrected vision. The tone scales were read with a spectrophotometer and a densitometer. Readings obtained and analyzed were; density, dot gain, print contrast, Lab, and Delta E (color difference). The tables, Chi Squares and ANOVAs describe the results of the data collection and analysis.

Establishing a Baseline

A baseline had to be established to ensure that the tone scales and halftones being studied were not significantly different from any other press runs that could have been conducted. Standards common to the printing industry were used. Countless tests have been completed throughout the industry to determine appropriate solid ink density, print contrast, gray balance, and dot gain. GRACoL 6 (General Requirements and Applications for Commercial Offset Lithography) suggests target ink densities and print contrast values achievable on a wide variety of equipment and consumable supplies. The press run completed at the printer utilized these suggested standards.

It was first determined that the printed tone scales using the alternative screening at 340 were not significantly different from sample to sample. The same was done for the alternative screening at 240 and the conventional screening. The paper and the inks were analyzed to determine if a difference occurred in the paper or the inks that could account for a difference in the printed tone scales, tint patches, or halftones. Gray balance is also easily analyzed when looking at the a* and b* values of the Black tone scales. When no difference was detected in the sample of tone scales, with the exception of yellow at 97%, it was inferred that there would be little or no difference in the printed halftones within the group selected for viewing. The results are as follows:

Table 4.1: Measured values of 100% patches using a Spectrophotometer

All colors Lab Values				
at 100%				
	SID	**L**	**a**	**b**
3-color black	1.2	34.65	11.83	0.69
Black	1.86	13.22	1.69	0.8
Green	1.13	55.14	-61.65	20.06
Magenta	1.41	48.98	72.3	-5.72
Red	1.42	48.78	66.64	41.97
Cyan	1.24	58.35	-34.49	-46.94
Blue	1.48	26.64	32.78	-39.55
Yellow	0.86	90.19	-7.95	83.8

Paper

The paper should have very little color variance. The light that is reflected from white paper is a combination of red, green, and blue which is perceived as white. If the paper has a measurable color difference from white before it is printed, it will affect the color after it is printed, if transparent inks (cyan, magenta, and yellow) are used. The color characteristics of the paper used in the printing of the halftones was measured and no significant difference was found with n=30. The variance at a 95% confidence interval for the L*, a*, and b* values was .08, .03, and .008 respectively. Therefore, the paper was found to be of the same color.

Variance of the Measured Process Inks Used for the Printing of the Samples

The inks used for printing the tint patches, tone scales, and halftones were measured with a spectrophotometer to determine Lab values. The measured variance of the process inks is as follows with n=30. The b* value of Yellow at 97% is of concern. This color variation could have caused the differences noticed in other parts of the study.

Table 4.2: Variance of the L* a* and b* values of Process color inks

	Cyan			**Magenta**			**Yellow**		
Dot %	**L***	**a***	**b***	**L***	**a***	**b***	**L***	**a***	**b***
97% Dot	0.39	0.32	0.47	0.22	1.28	0.10	0.01	0.00	4.23
50% Dot	0.14	0.16	0.17	0.28	0.83	0.10	0.02	0.04	1.46
10% Dot	0.04	0.05	0.07	0.13	0.14	0.02	0.01	0.03	0.47

Delta E or ΔE

Delta E is the Sum of Squares difference between two colors. The formula is the square root of the sum of squares difference between the lightness value, a value, and b value of color number one minus the lightness value, a value, and b value of color number two.

$$\Delta E = \sqrt{(L_1-L_2)^2 + (a_1-a_2)^2 + (b_1-b_2)^2}$$

The accepted difference varies by color based on the human eye's ability to see slight color variation differently depending on the color being viewed. Commonly, a Delta E of three or below is an acceptable color difference. The expectation would be higher if the color being measured was a specific brand related color like Clemson Orange or Coca Cola Red.

Table 4.3: Accepted Delta E

Color	Red	Green	Blue	Black
Accepted ΔE	ΔE at/or below 3	ΔE at/or below 3	ΔE at/or below 3	ΔE at/or below 3

Delta E of the Process Color Halftone Tints; HA-HB, HB-HC, and HA-HC

Color difference is imperceptible for all except the yellow halftone B and halftone C at a 97% dot. Again, this could account for some of the color differences in the tints and halftones using yellow.

Table 4.4: Delta E of Process Inks

Delta E of Cyan at 97%			**Delta E of Magenta at 97%**			**Delta E of Yellow at 97%**		
	Delta E	Diff		Delta E	Diff		Delta E	Diff
HA-HB	1.666295	No	HA-HB	2.516119	No	HA-HB	2.30837	No
HB-HC	2.027189	No	HB-HC	1.065066	No	HB-HC	4.713769	Yes
HA-HC	0.420435	No	HA-HC	1.585686	No	HA-HC	2.405661	No
Delta E of Cyan at 50%			**Delta E of Magenta at 50%**			**Delta E of Yellow at 50%**		
	Delta E	Diff		Delta E	Diff		Delta E	Diff
HA-HB	0.794283	No	HA-HB	1.592592	No	HA-HB	0.773078	No
HB-HC	0.3177	No	HB-HC	0.726428	No	HB-HC	1.940796	No
HA-HC	0.706737	No	HA-HC	0.950765	No	HA-HC	1.173482	No
Delta E of Cyan at 10%			**Delta E of Magenta at 10%**			**Delta E of Yellow at 10%**		

	Delta E	Diff		Delta E	Diff		Delta E	Diff
HA-HB	0.725401	No	HA-HB	1.006049	No	HA-HB	1.300238	No
HB-HC	0.505875	No	HB-HC	0.530118	No	HB-HC	0.343356	No
HA-HC	0.222836	No	HA-HC	0.481091	No	HA-HC	1.000293	No

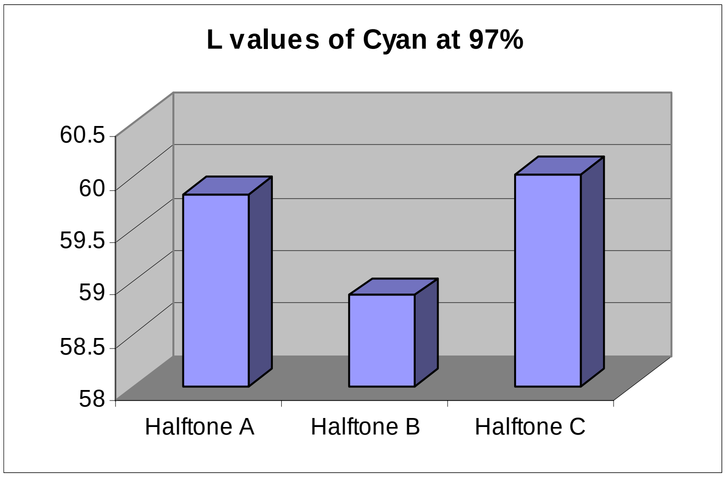
Charts of the Average Lab values of the Process Color Inks

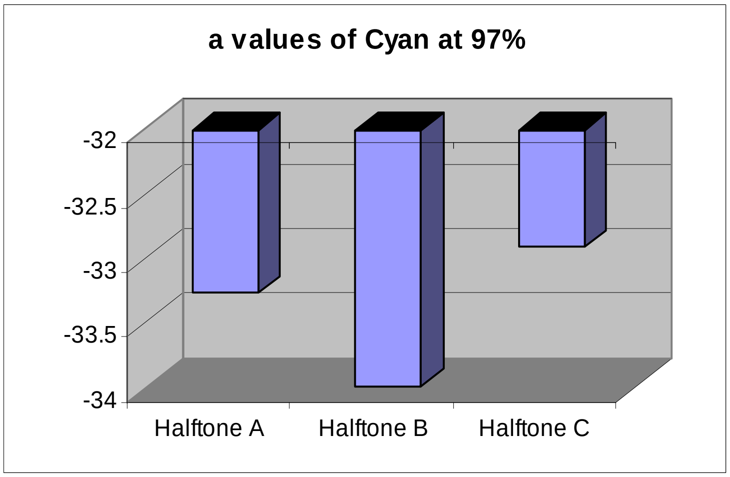
A visual representation is sometimes needed to display differences between items. Therefore, charts of the average Lab values of each halftone screening have been added to assist in establishing the baseline.

Table 4.5: Average Lab Values of Cyan at 97%

Average of L values	
Halftone A	59.823
Halftone B	58.87
Halftone C	60.013
Average of a values	
Halftone A	-33.263
Halftone B	-33.986
Halftone C	-32.908
Average of b values	
Halftone A	-45.063
Halftone B	-46.223
Halftone C	-44.942

Graph 4.5: Average Lab Values of Cyan at 97%





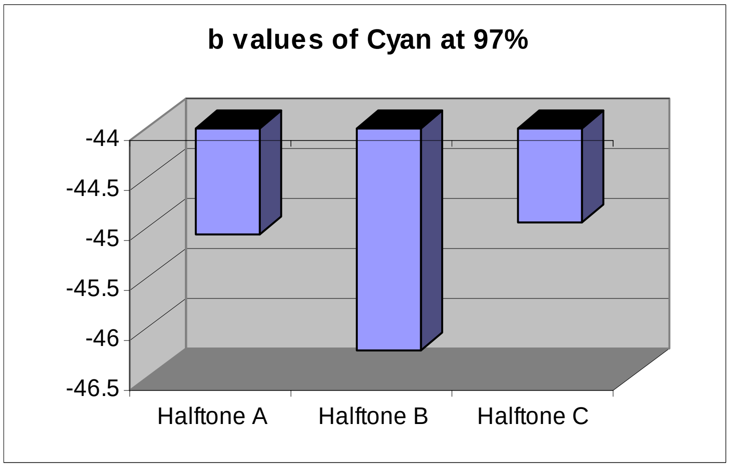
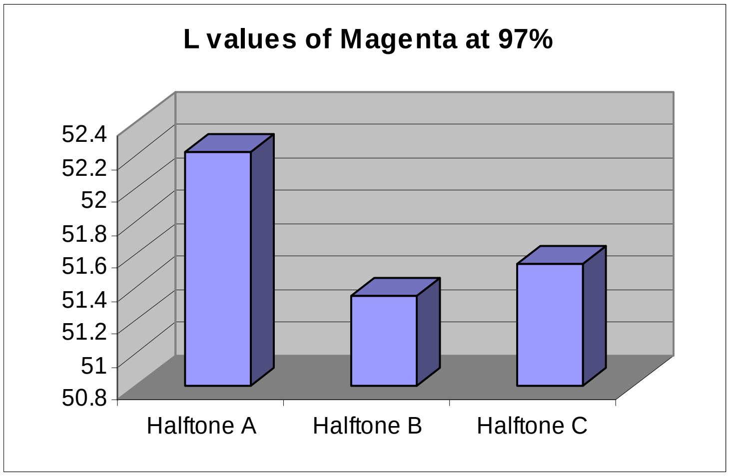
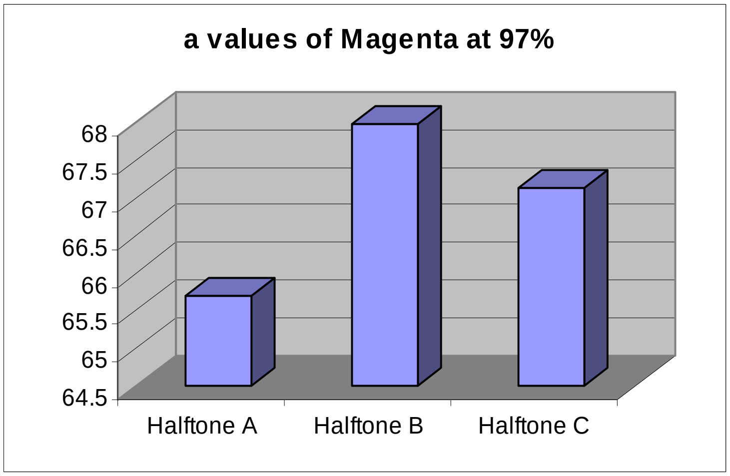


Table 4.6 Average Lab Values of Magenta at 97%

Average of L values	
Halftone A	52.231
Halftone B	51.354
Halftone C	51.55
Average of a values	
Halftone A	65.713
Halftone B	67.99
Halftone C	67.145
Average of b values	
Halftone A	-5.681
Halftone B	-6.295
Halftone C	-5.677

Graph 4.6 Average Lab Values of Magenta at 97%





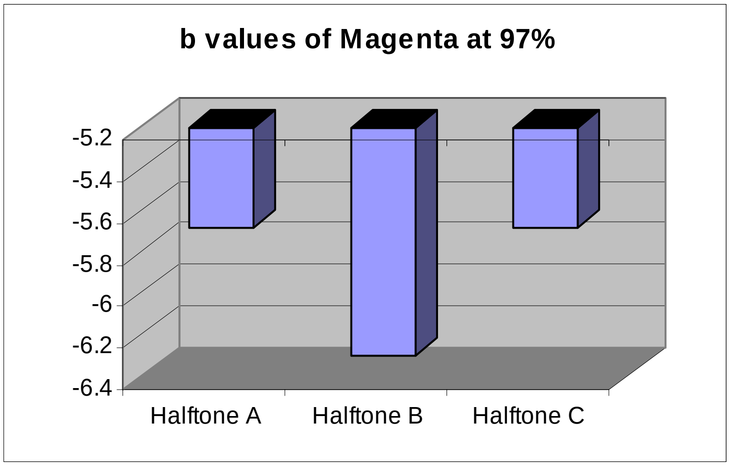
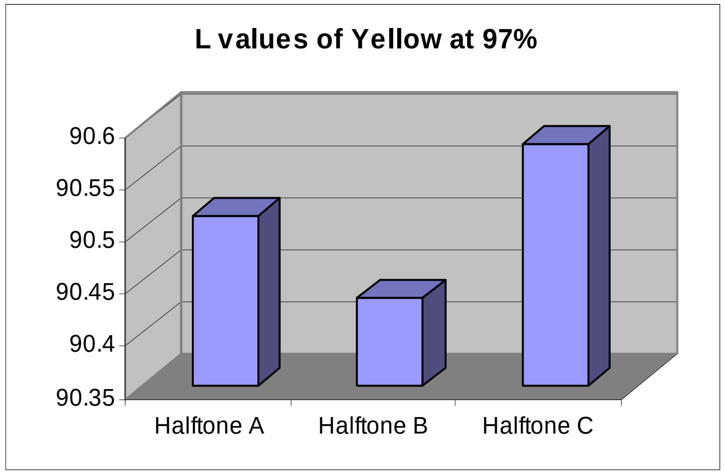
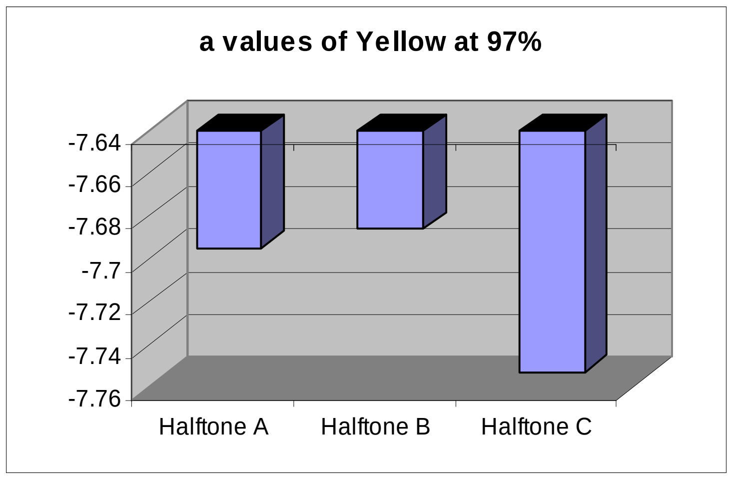


Table 4.7: Average Lab Values of Yellow at 97%

Average of L values	
Halftone A	90.513
Halftone B	90.434
Halftone C	90.581
Average of a values	
Halftone A	-7.695
Halftone B	-7.686
Halftone C	-7.753
Average of b values	
Halftone A	78.635
Halftone B	80.942
Halftone C	76.231

Graph 4.7 Average Lab Values of Yellow at 97%





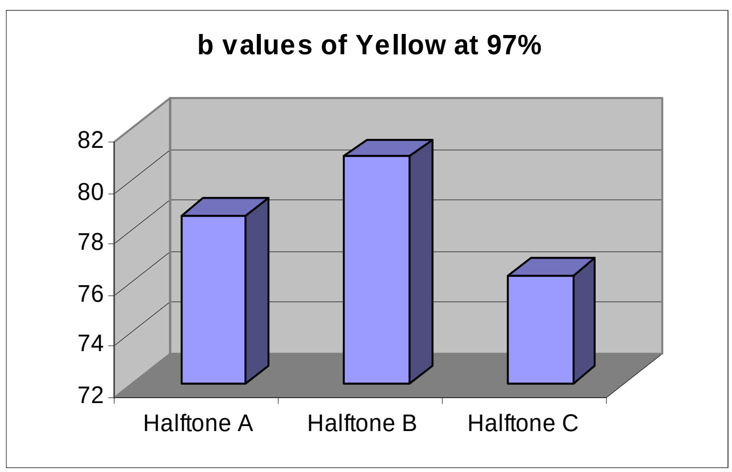
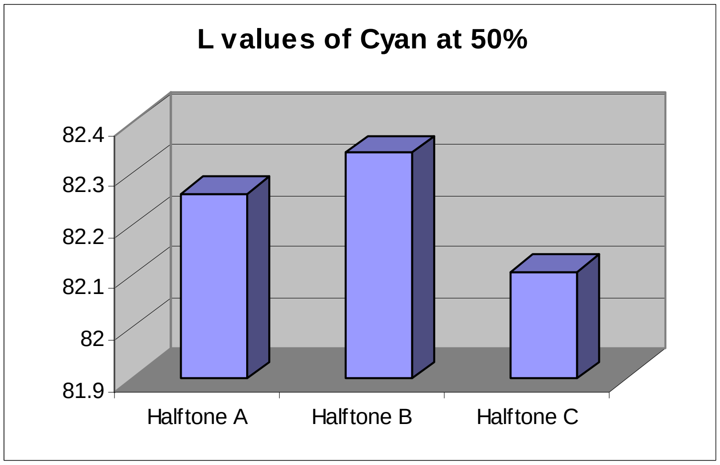
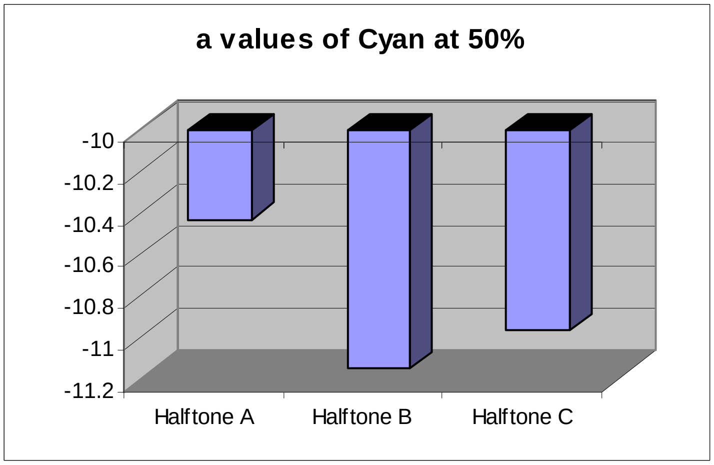


Table 4.8: Average Lab Values of Cyan at 50%

Average of L values	
Halftone A	82.261
Halftone B	82.342
Halftone C	82.108
Average of a values	
Halftone A	-10.43
Halftone B	-11.152
Halftone C	-10.968
Average of b values	
Halftone A	-17.84
Halftone B	-18.161
Halftone C	-18.272

Graph 4.8: Average Lab Values of Cyan at 50%





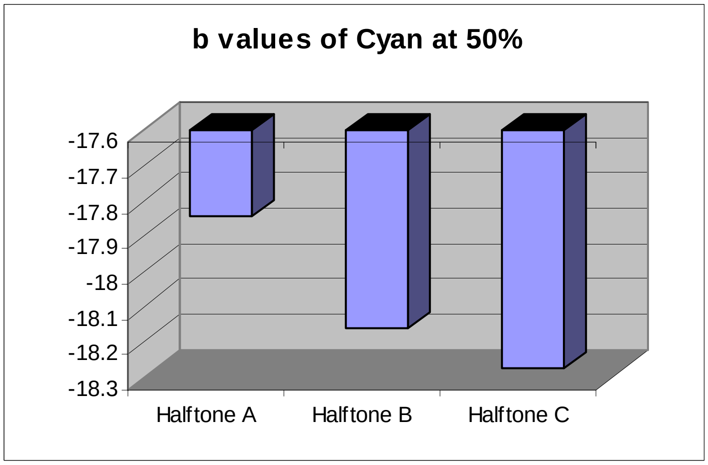
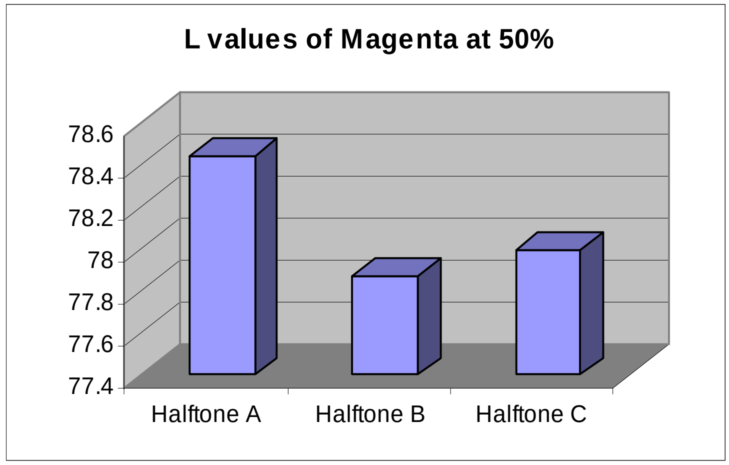
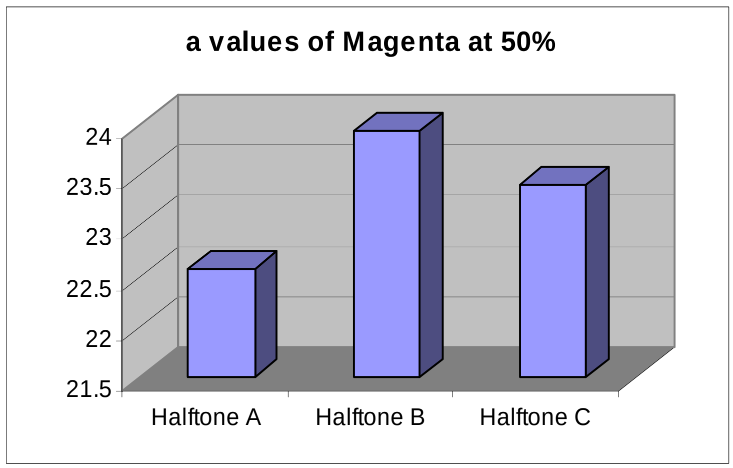


Table 4.9: Average Lab Values of Magenta at 50%

Average of L values	
Halftone A	78.444
Halftone B	77.871
Halftone C	77.995
Average of a values	
Halftone A	22.582
Halftone B	23.96
Halftone C	23.415
Average of b values	
Halftone A	-6.327
Halftone B	-6.883
Halftone C	-6.419

Graph 4.9: Average Lab Values of Magenta at 50%





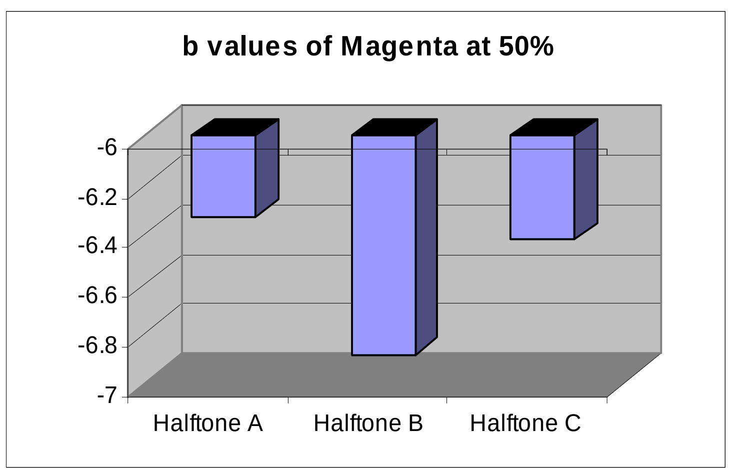
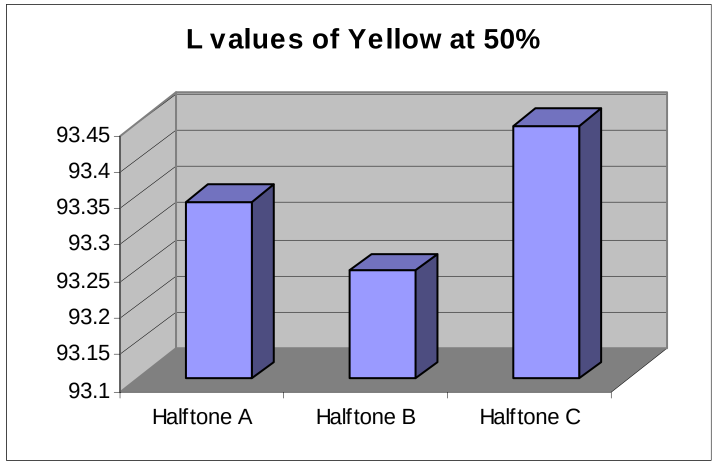
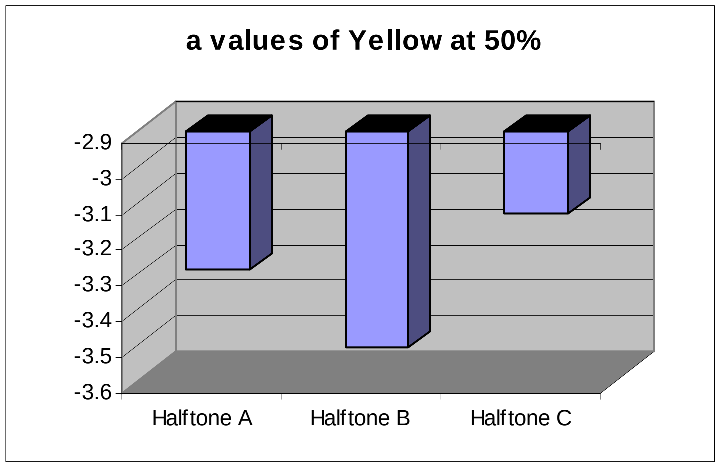


Table 4.10: Average Lab Values of Yellow at 50%

Average of L values	
Halftone A	93.342
Halftone B	93.247
Halftone C	93.446
Average of a values	
Halftone A	-3.289
Halftone B	-3.509
Halftone C	-3.13
Average of b values	
Halftone A	20.694
Halftone B	21.429
Halftone C	19.536

Graph 4.10: Average Lab Values of Yellow at 50%





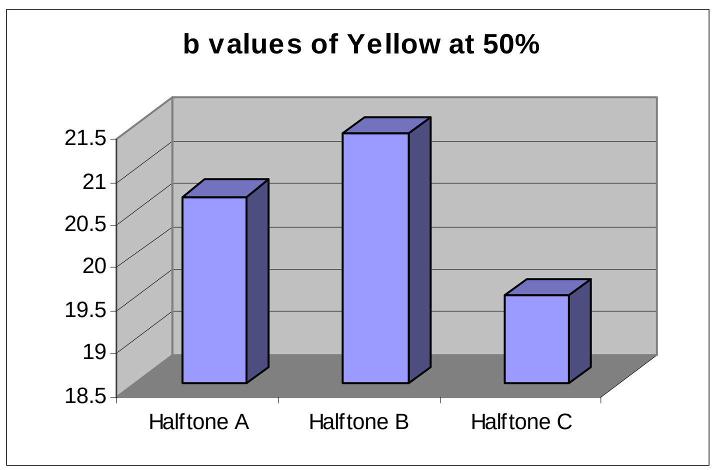
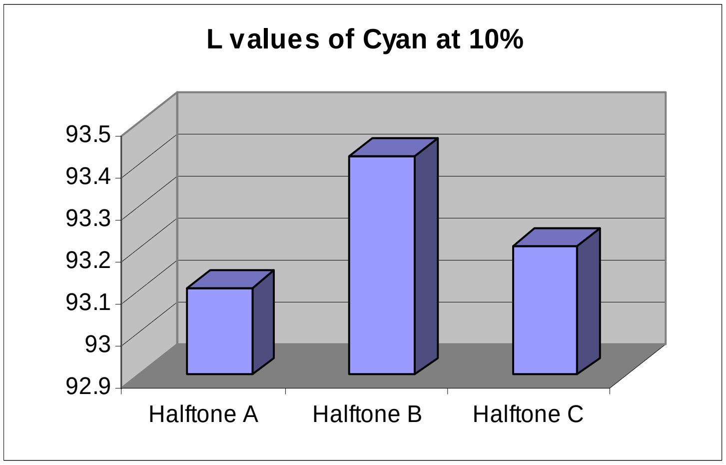
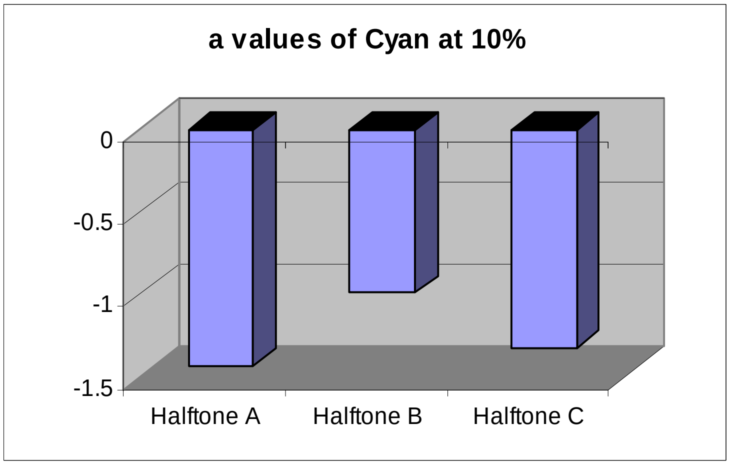


Table 4.11: Average Lab Values of Cyan at 10%

Average of L values	
Halftone A	93.106
Halftone B	93.42
Halftone C	93.206
Average of a values	
Halftone A	-1.435
Halftone B	-0.992
Halftone C	-1.325
Average of b values	
Halftone A	-5.236
Halftone B	-4.755
Halftone C	-5.07

Graph 4.11: Average Lab Values of Cyan at 10%





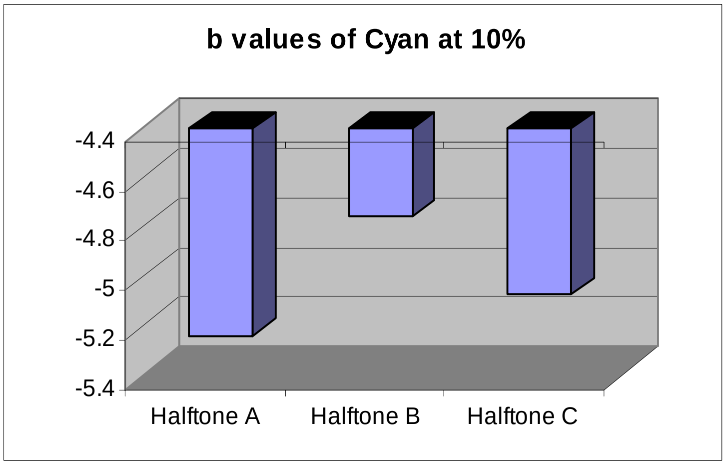
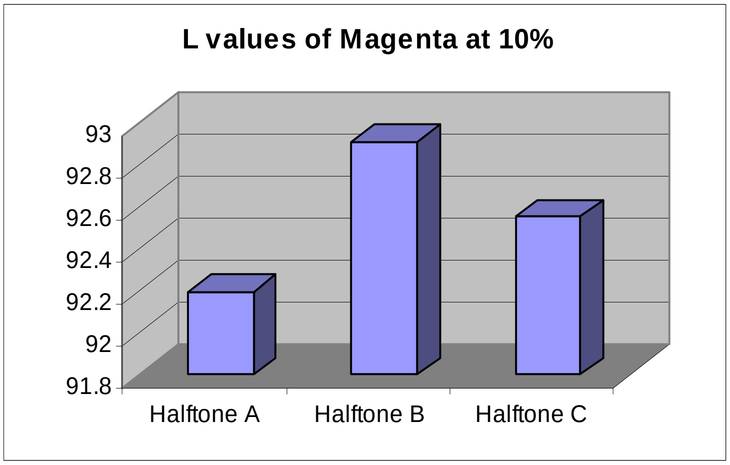
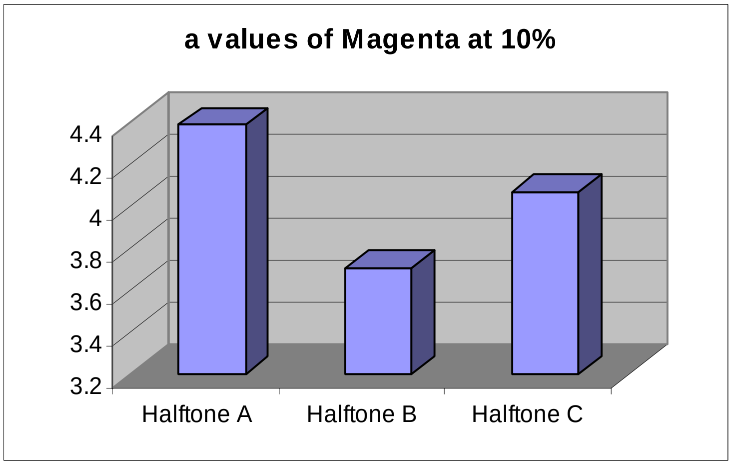


Table 4.12: Average Lab Values of Magenta at 10%

Average of L values	
Halftone A	92.194
Halftone B	92.909
Halftone C	92.553
Average of a values	
Halftone A	4.391
Halftone B	3.706
Halftone C	4.073
Average of b values	
Halftone A	-3.719
Halftone B	-3.541
Halftone C	-3.681

Graph 4.12: Average Lab Values of Magenta at 10%





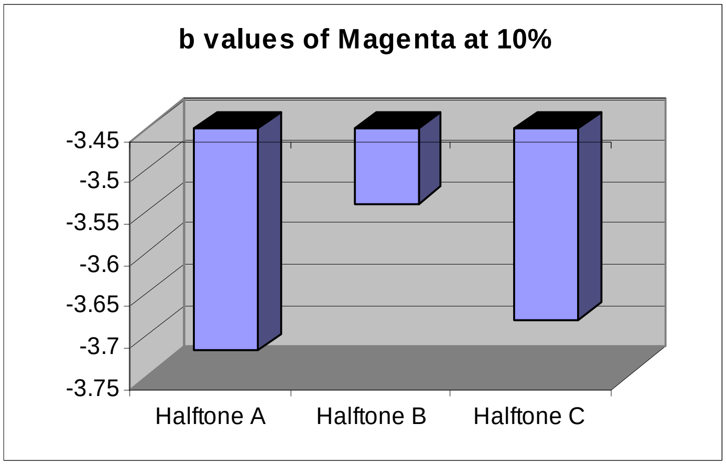
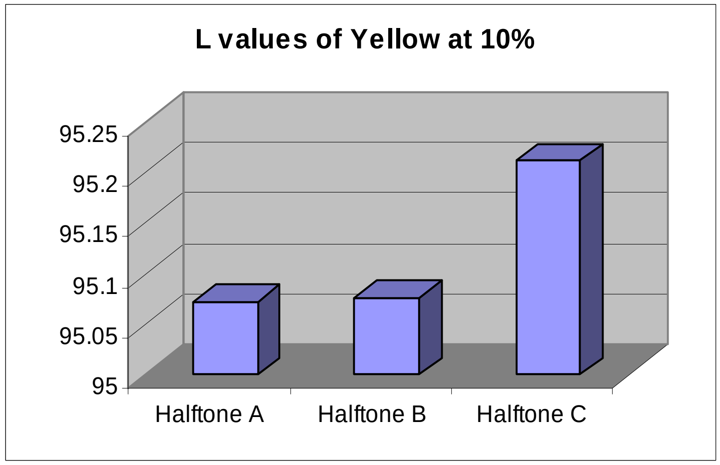
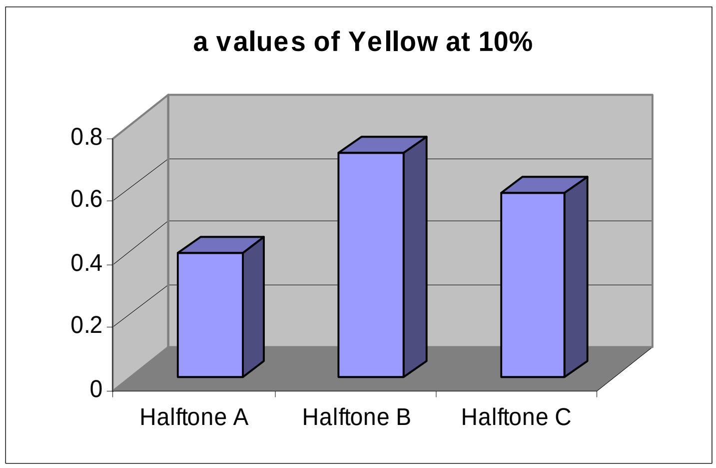


Table 4.13: Average Lab Values of Yellow at 10%

Average of L values	
Halftone A	95.073
Halftone B	95.076
Halftone C	95.212
Average of a values	
Halftone A	0.393
Halftone B	0.71
Halftone C	0.584
Average of b values	
Halftone A	-1.433
Halftone B	-2.694
Halftone C	-2.405

Graph 4.13: Average Lab Values of Yellow at 10%





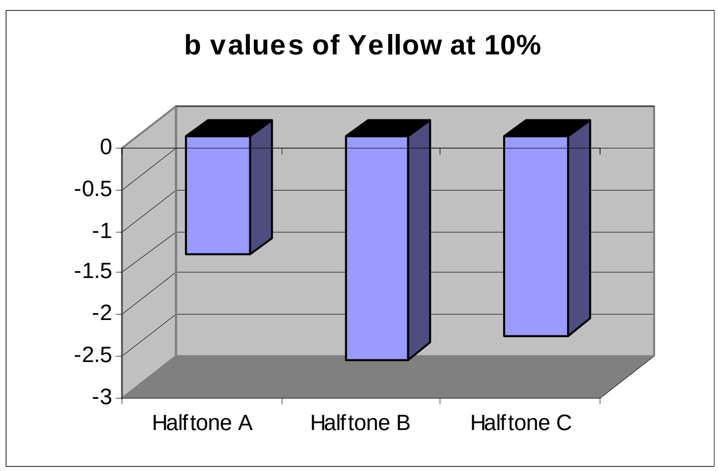
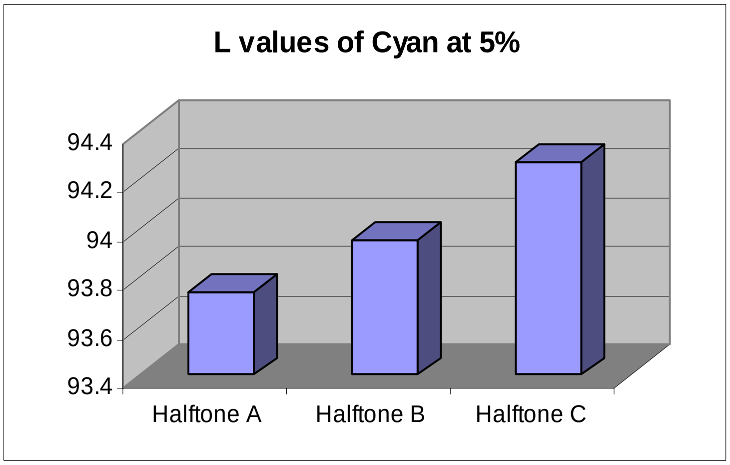
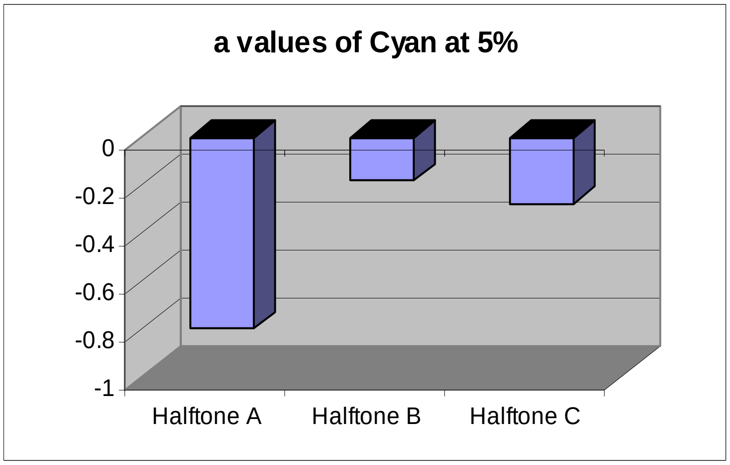


Table 4.14: Average Lab Values of Cyan at 5%

Average of L values	
Halftone A	93.74
Halftone B	93.953
Halftone C	94.272
Average of a values	
Halftone A	-0.802
Halftone B	-0.183
Halftone C	-0.276
Average of b values	
Halftone A	-4.475
Halftone B	-3.825
Halftone C	-3.828

Graph 4.14: Average Lab Values of Cyan at 5%





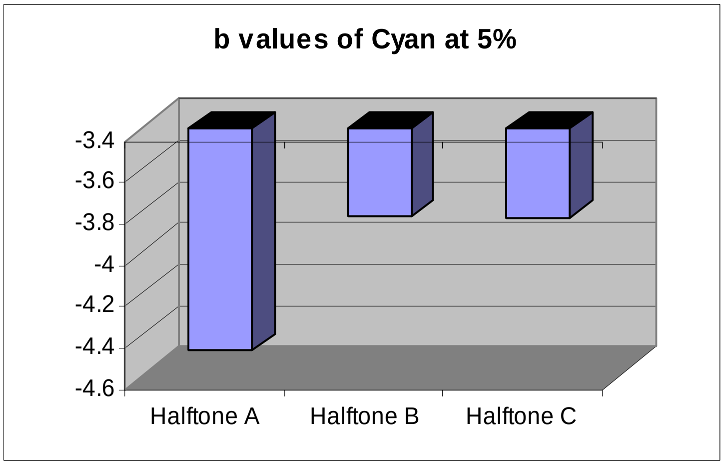
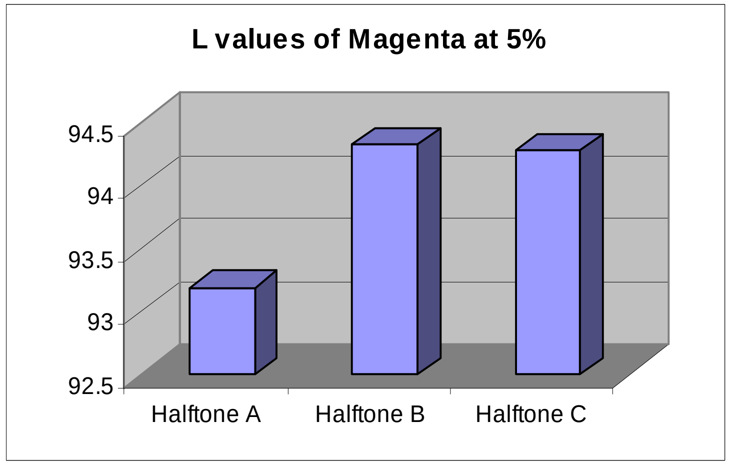
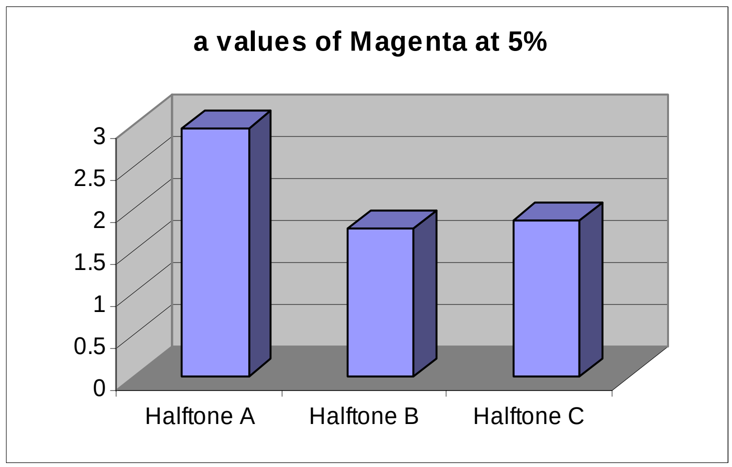


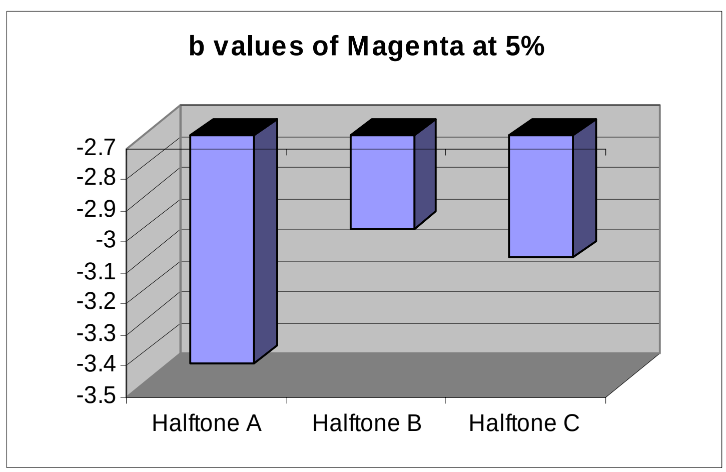
Table 4.15: Average Lab Values of Magenta at 5%

Average of L values	
Halftone A	93.19
Halftone B	94.322
Halftone C	94.278
Average of a values	
Halftone A	2.975
Halftone B	1.777
Halftone C	1.866
Average of b values	
Halftone A	-3.432
Halftone B	-2.998
Halftone C	-3.094

Graph 4.15: Average Lab Values of Magenta at 5%







Measurement and Evaluation of the Tint Patches and Tone Scales

The hypothesis suggests than an alternative (XM) screening method will significantly change the measured values, (i.e. Lab values, Delta E, dot gain, and print contrast) when compared to conventional screening reproduced on coated paper and an offset lithographic press. The null is written as an alternative (XM) screening method will show no significant difference in the measured values, (i.e. Lab values, dot gain, and print contrast) when compared to conventional screening reproduced on coated paper and an offset lithographic press. Therefore, if the average of the Delta E of the Lab values of each color measured falls below the acceptable standard of a Delta E of 3, then the null is true and cannot be rejected. The results following are broken down into areas of interest; shadows at 97%, midtones at 50%, and highlights at 10% and 5%. It was discovered through the measurements and Delta E calculations that although instrumentation shows a difference, the difference is imperceptible to the human eye.

Shadows

The dark areas of the halftones must show detail while maintaining fidelity of color when compared to the original. Shadows are of particular importance in halftones containing things like a leather jacket with dark sunglasses or a bronze statue. Detail in the shadows is often lost in a halftone with a full range of tones because the highlights may need more detail and the tones must be compressed to show more detail in the highlights. The red, blue, and green overprinted tone scales were measured with a spectrophotometer at/around the 97% dot area. The alternative screening method utilizes an FM dot in the shadows while the conventional maintains the same dot orientation throughout, therefore the measured Delta E must be studied in this area of the tone scale. The Delta E was calculated between the two alternative screenings HA and HB, then each alternative was compared to the conventional screening, HA to HC and HB to HC. The results are as follows.

Table 4.16: Delta E of the Shadows

Delta E of the Averages of Red at 97%			Delta E of the Averages of Blue at 97%		
	Delta E	Null		Delta E	Null
HA-HB	2.742295	Fail to Rej.	HA-HB	1.622725	Fail to Rej.
HB-HC	1.594916	Fail to Rej.	HB-HC	0.796649	Fail to Rej.
HA-HC	1.722445	Fail to Rej.	HA-HC	1.123326	Fail to Rej.
Delta E of the Averages of Green at 97%					
	Delta E	Null			
HA-HB	2.966327	Fail to Rej.			
HB-HC	1.350065	Fail to Rej.			
HA-HC	4.202157	Reject			

Midtones at 50%

The mid-tone areas of printed halftones are critical for color matches of lighter skin tones, clothing, and wood grain. The red, blue, and green overprinted tone scales were measured with a spectrophotometer at/around the 50% dot area. The alternative screening method utilizes a conventional dot structure in the midtones, which should maintain very similar colors as determined by the measured Delta E. The Delta E was calculated between the two alternative screenings HA and HB, then each alternative was compared to the conventional screening, HA to HC and HB to HC. The results are:

Table 4.17: Delta E of the Midtones

Delta E of the Averages of Red at 50%			Delta E of the Averages of Blue at 50%		
	Delta E	Null		Delta E	Null
HA-HB	3.422347	Reject	HA-HB	1.532615	Fail to Rej.
HB-HC	1.385399	Fail to Rej.	HB-HC	2.656751	Fail to Rej.
HA-HC	2.043709	Fail to Rej.	HA-HC	1.306791	Fail to Rej.
Delta E of the Averages of Green at 50%					
	Delta E	Null			
HA-HB	2.219328	Fail to Rej.			
HB-HC	1.021597	Fail to Rej.			
HA-HC	1.203765	Fail to Rej.			

Highlights at 10% and 5%

The highlight areas of printed halftones are critical for color matches and the detail displayed in baskets of eggs, wedding dresses, and white curtains with sunlight shining through a window. The red, blue, and green overprinted tone scales were measured with a spectrophotometer at/around the 10% and 5% dot areas. The alternative screening method utilizes an FM dot structure in the highlights, while the conventional maintains an AM dot structure throughout. The alternative screening @ 340 breaks from AM to FM at/around a 14% dot and the alternative screening @ 240 breaks from AM to FM at/around an 8% dot. Therefore, the measured Delta E must be studied in these areas of the tone scales. The Delta E was calculated between the two alternative screenings HA and HB, then each alternative was compared to the conventional screening, HA to HC and HB to HC. The results are as follows.

Table 4.18: Delta E of the Highlights

Delta E of the Avg of Red at 10%			Delta E of the Avg of Blue at 10%		
	Delta E	Null		Delta E	Null
HA-HB	1.486231	Fail to Rej.	HA-HB	2.215893	Fail to Rej.
HB-HC	0.721632	Fail to Rej.	HB-HC	0.198962	Fail to Rej.
HA-HC	0.766696	Fail to Rej.	HA-HC	2.402636	Fail to Rej.
Delta E of the Avg of Green at 10%			Delta E of the Avg of Red at 5%		
	Delta E	Null		Delta E	Null
HA-HB	0.760164	Fail to Rej.	HA-HB	1.809927	Fail to Rej.
HB-HC	0.288804	Fail to Rej.	HB-HC	0.169296	Fail to Rej.
HA-HC	0.481101	Fail to Rej.	HA-HC	1.765914	Fail to Rej.
Delta E of the Avg of Blue at 5%			Delta E of the Avg of Green at 5%		
	Delta E	Null		Delta E	Null
HA-HB	1.885167	Fail to Rej.	HA-HB	1.901306	Fail to Rej.
HB-HC	0.182464	Fail to Rej.	HB-HC	0.211976	Fail to Rej.
HA-HC	1.97372	Fail to Rej.	HA-HC	1.701223	Fail to Rej.

3-color and 4-color overprints of Black

Overprints of black are of particular interest in that subtle differences from true gray are easily detectable with the human eye. 3-color overprints of cyan, magenta, and yellow are used to determine gray balance, a printing control that is widely recognized as an effective method of controlling color on press. Measurements of both the 3-color and 4-color grayscales were taken to determine gray balance fidelity. The a* and b* values should be very close to 0. Otherwise, the gray will have a subtle color difference or caste of red, blue, or green. The Delta E was calculated between the two alternative screenings HA and HB, then each alternative was compared to the conventional screening, HA to HC and HB to HC. The results are as follows.

Table 4.19: Delta E of the 3C and 4C Overprints

Delta E of Avg of 4-C Black at 97%			Delta E of Avg of 4-C Black at 50%		
	Delta E	Null		Delta E	Null
HA-HB	3.156235	Reject	HA-HB	1.840635	Fail to Rej.
HB-HC	5.618293	Reject	HB-HC	1.801003	Fail to Rej.
HA-HC	4.009427	Reject	HA-HC	0.594075	Fail to Rej.
Delta E of Avg of 4-C Black at 10%			Delta E of Avg of 4-C Black at 5%		
	Delta E	Null		Delta E	Null
HA-HB	1.067192	Fail to Rej.	HA-HB	1.400439	Fail to Rej.
HB-HC	0.517523	Fail to Rej.	HB-HC	0.261559	Fail to Rej.
HA-HC	1.446329	Fail to Rej.	HA-HC	1.158277	Fail to Rej.
Delta E of Avg of 3-C Black at 97%			Delta E of Avg of 3-C Black at 50%		
	Delta E	Null		Delta E	Null
HA-HB	3.270585	Reject	HA-HB	2.147508	Fail to Rej.
HB-HC	2.888872	Fail to Rej.	HB-HC	2.581498	Fail to Rej.
HA-HC	2.815621	Fail to Rej.	HA-HC	0.893752	Fail to Rej.
Delta E of Avg of 3-C Black at 10%			Delta E of Avg of 3-C Black at 5%		
	Delta E	Null		Delta E	Null
HA-HB	0.845372	Fail to Rej.	HA-HB	1.308668	Fail to Rej.
HB-HC	0.581399	Fail to Rej.	HB-HC	0.130445	Fail to Rej.
HA-HC	1.374827	Fail to Rej.	HA-HC	1.193497	Fail to Rej.

Density, Dot Area, and Dot Gain

Density is the measure of the degree of opacity of an image on paper or film. (Agfa, 1993) Solid ink density targets have been used as quality control devices for most printing processes. Color bars at the tail of a lithographic press sheet are widely used to control the amount of ink delivered to the press sheet.

Dot area is the apparent size of a printed dot in relation to the substrate. It could be generally described as a percentage of substrate covered with ink. Dot area is generally measured with a densitometer.

Dot gain or tone value increase is, in one respect, the darkening of a halftone image when ink absorption in paper causes halftone dots to enlarge. For example, a 72% apparent dot area resulting from a 50% input is reported as a 22% dot gain. Another is the scattering of light around the ink film which causes the dot to appear larger. Dot gain is broken into these two categories respectively, physical dot gain and optical dot gain. All printing processes have dot gain. By using standardized materials with an extensive quality-control program, the amount of dot gain can be predicted and controlled. (Bridgs, 2005)

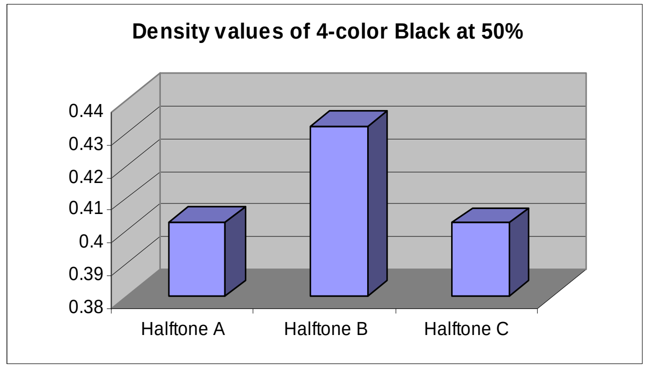
Table 4.20: Average Density, Dot Percent, and Dot Gain of 50% Tint Patches 4-color Black

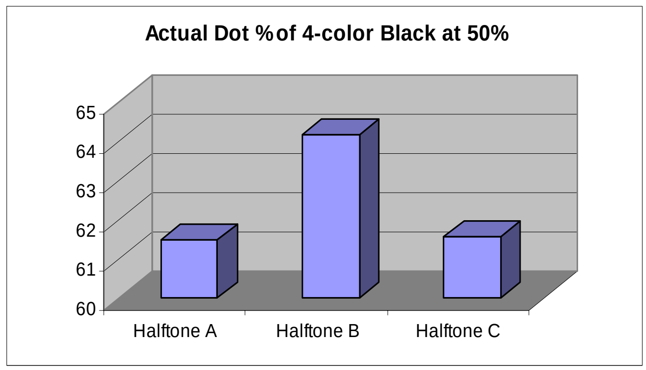
Average of Density values	
Halftone A	0.40275
Halftone B	0.43225
Halftone C	0.4025
Average Dot Percent	
Halftone A	61.5
Halftone B	64.2
Halftone C	61.575
Average Dot Gain	
Halftone A	11.5
Halftone B	14.2
Halftone C	11.575

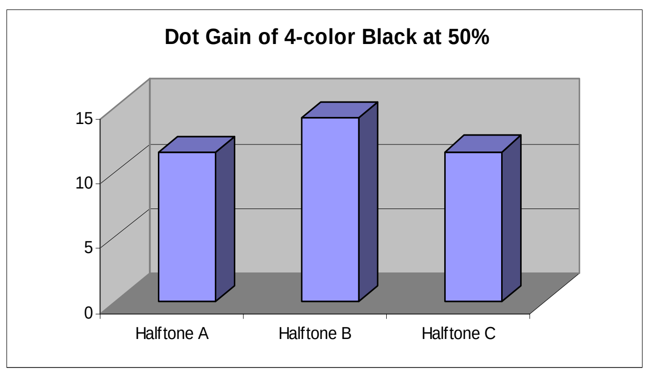
Table 4.21: Difference determined by lsd

Density		
t=	1.980447	
lsd=	0.002184	
Mean diff		
HA - HB	-0.0295	**Diff**
HB - HC	0.02975	**Diff**
HA - HC	0.00025	**No Diff**
Dot %		
t=	1.980447	
lsd=	0.21818	
Mean diff		
HA - HB	-2.7	**Diff**
HB - HC	2.7	**Diff**
HA - HC	0	**No Diff**
Dot Gain		
t=	1.980447	
lsd=	0.217314	
Mean diff		
HA - HB	-2.7	**Diff**
HB - HC	2.625	**Diff**
HA - HC	-0.075	**No Diff**

Graph 4.20: Average Density, Dot Percent, and Dot Gain of 50% Tint Patches 4-color Black







Print Contrast

Print contrast is the process of comparing the density readings of a three-quarter (around 75%) tone tint area and a solid patch. Print contrast indicates the printing system's ability to hold image detail in the upper tone region. (Bridgs, 2005) Without this detail, everything in the shadows would appear as a one tone dark area where differences should be displayed. All of these measures are accepted standards for controlling print work and the analysis is as follows:

Table 4.22: Difference in Print Contrast determined by lsd

PC for 3-color Black		
t=	2.051829	
lsd=	0.815012	
Mean diff		
HA - HB	4.9	**Diff**
HB - HC	-1.9	**Diff**
HA - HC	3	**Diff**

PC for 4-color Black		
t=	2.051829	
lsd=	0.785791	
Mean diff		
HA - HB	2.6	**Diff**
HB - HC	-3.1	**Diff**
HA - HC	-0.5	**No Diff**

PC for Magenta		
t=	2.051829	
lsd=	0.937775	
Mean diff		
HA - HB	-0.8	**No Diff**
HB - HC	-0.9	**No Diff**
HA - HC	-1.7	**Diff**

PC for Red		
t=	2.051829	
lsd=	2.925806	
Mean diff		
HA - HB	1.8	**No Diff**
HB - HC	5.9	**Diff**
HA - HC	7.7	**Diff**

PC for Cyan		
t=	2.051829	
lsd=	2.633551	
Mean diff		
HA - HB	6.6	**Diff**
HB - HC	-4.6	**Diff**
HA - HC	2	**No Diff**

PC for Yellow		
t=	2.051829	
lsd=	0.728113	
Mean diff		
HA - HB	6.7	**Diff**
HB - HC	-6.3	**Diff**
HA - HC	0.4	**No Diff**

Subjective Quality Evaluation

Chi Square

The purpose of this study is to determine if the alternative screening method improves the apparent quality of the halftones when viewed by a random selection of viewers. 130 people evaluated the printed halftones (HA, HB, and HC) and made choices of which they thought was the highest quality, based on five criteria for determining quality; color balance, saturation, contrast, sharpness, and detail.

The Hypothesis is written to suggest that the alternative screening method will improve the apparent quality of the printed halftones. Therefore, the null hypothesis would be that there is no difference. The Chi Square statistic was completed with the three different screenings and analyzed for differences in printing experience, vision, and gender. The choice of no difference was not factored into the statistical analysis but must be observed when making the final conclusions. Therefore, the choice of no difference is set to the right of alpha at .05. The results are as follows:

Table 4.23: Chi Square of Choices Made During the Evaluation of the Halftones

Total # of Choices made	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	580	844	533	86.166	5.991	1268
Expected	652.333	652.333	652.333		Reject	
Non-Printers Iguana	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	50	108	35	46.207	5.991	207
Expected	64.333	64.333	64.333		Reject	
Non-Printers Cougar	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	44	164	60	95.045	5.991	132
Expected	89.333	89.333	89.333		Reject	

Non-Printers Leaf	HA	HB	HC	X2	alpha 0.05	No Diff
Observed	106	62	83	11.578	5.991	149
Expected	83.667	83.667	83.667		Reject	
Non-Printers Spools	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	71	59	73	1.695	5.991	197
Expected	67.667	67.667	67.667		Fail to	
Non-Printers Hallway	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	60	100	46	22.874	5.991	194
Expected	68.667	68.667	68.667		Reject	
Printers Iguana	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	15	71	71	39.949	5.991	88
Expected	52.333	52.333	52.333		Reject	
Printers Cougar	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	39	127	35	80.716	5.991	44
Expected	67	67	67		Reject	
Printers Leaf	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	63	54	51	1.393	5.991	77
Expected	56	56	56		Fail to	
Printers Spools	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	59	46	36	5.66	5.991	104
Expected	47	47	47		Fail to	
Printers Hallway	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	73	53	43	8.284	5.991	76
Expected	56.333	56.333	56.333		Reject	
Printers w/ Corrected Vision Iguana	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	3	46	32	35.63	5.991	54
Expected	27	27	27		Reject	
Printers w/ Uncorrected	**HA**	**HB**	**HC**	**X2**	**alpha**	**No**

Vision Iguana					**0.05**	**Diff**
Observed	7	14	33	20.111	5.991	17
Expected	18	18	18		Reject	
Printers Male Iguana	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	7	40	47	29.128	5.991	46
Expected	31.333	31.333	31.333		Reject	
Printers Female Iguana	**HA**	**HB**	**HC**	**X2**	**alpha 0.05**	**No Diff**
Observed	2	20	18	14.6	5.991	25
Expected	13.333	13.333	13.333		Reject	

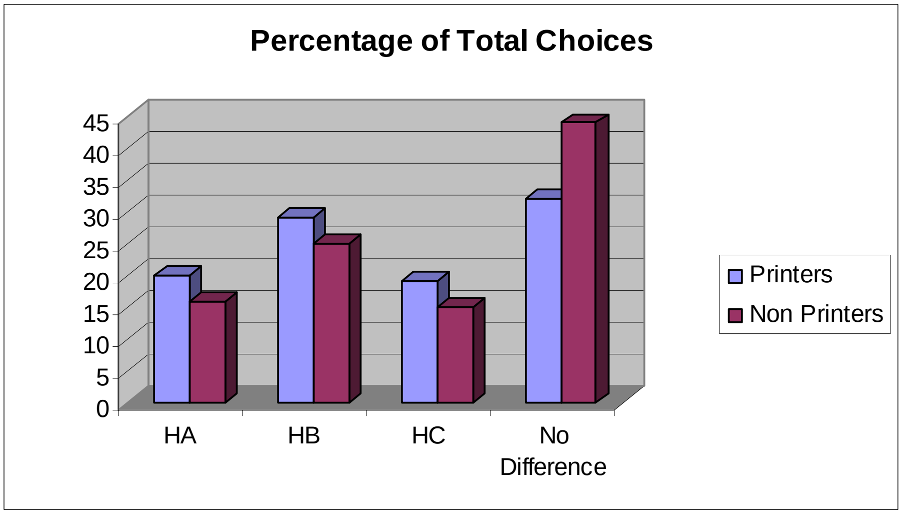
Percentage of Total Choices

The total possible choices that could have been made considering all halftones were 1,225 for Printers and 2,000 for Non-Printers. The following table and chart are a description of the choices made. A further analysis of the choices made during the evaluation is located in the appendix.

Table 4.24: Percentage of Total Choices made by Halftone

Halftone	Printers	Non Printers
HA	20%	16%
HB	29%	25%
HC	19%	15%
No Difference	32%	44%

Graph 4.24 Percentage of Total Choices



CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Summary

Printers are still concerned with craftsmanship and are always looking for means to produce faster print jobs with improved quality. The invention of new halftone screening techniques is one of the methods imaging companies have used to improve the quality of the printed piece. FM and Hybrid techniques can possibly improve the aesthetic qualities and fidelity of printed reproductions, therefore printers and students of printing need to study these techniques to ensure that the benefits outweigh the costs of implementation.

This experimental study was conducted to measure the quality of printed halftones that were screened with three different dot structures; conventional, alternative (XM) at 240 lpi, and alternative (XM) at 340 lpi. The press sheet designed by the researcher was sent to Agfa for plating. The printing of the halftones and tone scales was completed using accepted printing practices.

The analysis was focused on two questions; is there a difference in the tone scales created with the use of the alternative screening, and is there an improvement of the apparent quality of the halftones when evaluated?

The tone scales and tint patches were read with a densitometer and spectrophotometer. The data was entered and analyzed.

Packets for viewing were constructed containing all the elements necessary to administer the evaluation and complete the survey instrument. This information was then categorized and input for analysis.

Statement of the Problem

In the printing world, how good is good enough? Acceptable quality for halftones has become photographic print quality. With any printing method, printers are attempting to approach photo quality. In a conversation, Page Crouch, of Clemson University stated, "Lithographic printing has achieved quality very close to photographic quality." With all of the different possibilities for screening, scanning, imagesetting, platesetting, and direct to press, printers and graphic communications hardware and software inventors remain intent on improving the apparent quality of the halftone. The problem is better defined with the following questions; can the halftone be improved with the use of an alternative screening? If so, is it commercially feasible, and what are the costs associated with the change to another screening method?

Significance/Purpose of the Study

The purpose of this study is to determine if significant improvements can be made in halftone reproduction by implementing an alternative screening (XM) method when compared to a conventional (AM) screening. The data from this independent comparative analysis will enable printers to make a more informed decision when considering an investment in an alternative screening method.

Research Questions

Research Question 1

Does using the alternative (XM) screening method significantly improve the apparent quality of halftone reproduction when compared to conventional screening method when reproduced on coated paper using an offset lithographic press?

Research Question 2

Will using the alternative (XM) screening method significantly change the measured values, (i.e. Lab values, Delta E, dot gain, and print contrast) when compared to conventional screening method reproduced on coated paper using an offset lithographic press?

Research Hypotheses

Research Hypothesis 1

Using an alternative (XM) screening method will significantly improve the apparent quality of halftone reproduction when compared to conventional screening method reproduced on coated paper using an offset lithographic press.

Research Hypothesis 2

Using an alternative (XM) screening method will significantly change the measured values, (i.e. Lab values, Delta E, dot gain, and print contrast) when compared to conventional screening method reproduced on coated paper using an offset lithographic press.

Results

Lab values were collected for 3-color Black, 4-color Black, Red, Green, Blue, Cyan, Magenta, and Yellow. Print contrast values were collected for 3-color Black, 4-color Black, Cyan, Magenta, and Yellow. Density and dot gain values were calculated on 4-color Black at 50%. The measured differences of these areas show a significant difference between the halftones. ANOVAs and least squared difference statistics were completed to determine if a difference occurred. Graphs of the average Lab values were created. All results clearly show there is a measured difference in the tint patches and the tone scales.

Chi Square analysis was performed on the data collected from the survey completed by the evaluation participants. Printers were compared to non printers, those with corrected vision to those with uncorrected vision, and males to females. The analysis suggests there is a perceptible difference in the halftones.

Conclusions

Standardized measurements for determining print quality were performed on the tint scales and patches to determine if a significant difference was created by using the alternative (XM) screening. The overwhelming conclusion is that there is a significant difference in all three screening types when comparing Lab values, dot gain, and print contrast. Yet the Delta E values do not suggest a significant difference. Delta E is the standard measure of color difference, for the printing industry, and is used to describe the human eye's ability to detect color difference.

For the human participants evaluation of the halftones, the prints were rated on the five criteria; color balance, saturation, contrast, sharpness, and detail. These terms are consistently used in the printing industry to describe the quality of printing. The printed halftones show a difference when the data is collected via the evaluation of halftones survey (Appendix C).

The most interesting component of this research is although there is a statistically significant difference in the tone scales and the printed halftones when measured with printing industry equipment, the human evaluation data (Delta E and selection) does not support that one screening method is better than the other. Many people reported that they saw no difference; the average number was thirty-two percent for printers and forty-four percent for non-printers. The viewing participants who did see a higher quality in one versus the other were fairly equally spread across the three screening methods and quality factors. Those results are listed in Chapter 4.

Therefore, the only conclusion that can be drawn from this research is there is an obvious difference in the measured values of the different screening methods. However, Alan Warner of Houston Desktop Graphics, who also participated in the study, concisely stated “There is no commercially significant difference in the halftones”. In other words, investing resources to begin using this alternative (XM) screening method for offset lithographic work on coated paper would be nothing more than different.

Recommendations

Recommendations for further consideration should include a possible comparison of the ease of printing with the alternative screening as compared to conventional ABS screening. It is possible that the use of FM dots in the highlights and shadows could allow a greater margin for error in ink and water balance without dropping or filling in the dots which provide detail in those areas.

A researcher could focus attention on the workflow issues or time savings. Each could show an improvement which would save money over time and speed the return on investment and increase the profit margin over the long term.

The most compelling recommendation is to determine the psychology of the people who viewed the prints by studying their desire to find a difference. When the participants were given the instructions, they wanted to know what they were looking for that was different. They seemed to have a pre-conceived idea that there must be a difference. People who have never judged printing before suddenly found differences. Few saw no difference regardless of previous training in discernment of quality differences. Is it that they want to please the person collecting the data, or is it that they feel that they will not be seen as diligent if they do not determine a difference? The study could be set up to have the same group complete the evaluation at two different times. One administration could be done the same as above, with different screenings and one could be completed using all the same screenings. Would the choices look similar to this study?

Another limitation of this study included the use of two different alternative (XM) screenings compared to one conventional screening. This allowed for the alternative (XM) screening to be chosen one hundred percent more times than the conventional screening. The next study could include a comparison of one of each type of screening. Possibly, the researcher would want to compare conventional, hybrid, and stochastic screening methods.

APPENDICES

Appendix A

Informational Letter

Description of the research and your participation

You are being invited to participate in a Doctoral Dissertation Study involving the principal investigator, Samuel Ingram, Professor, and Garth Oliver, a student enrolled at Clemson University in the Vocational/Technical Education Ed.D program. As part of the requirements for the degree, data are collected for a research study. The purpose of this study is to determine which halftone screening method will produce the highest quality halftone reproduction. Thirty people in each of three groups (print professionals, press operators, and graphics students over age 18) have been invited to participate.

As part of the research procedures, you will be asked to complete a rating of five sets of printed halftones with three different screening methods. Information from this study will allow us to know more about the quality of different screening techniques. This survey will take about 15 minutes to complete and is anonymous.

Risks or Potential benefits

There are no known risks involved with your participation in this study. The only known benefit from your participation in this study will be the knowledge gained surrounding the use of alternate screenings in lithographic reproduction.

Protection of confidentiality

We will do everything we can to protect your privacy. Your name will not be associated with your survey. The demographic data could potentially identify you, but will be secured in Mr. Oliver's home and will be shredded upon completion of the study. Your identity will not be revealed in any publication that might result from this study.

Voluntary participation

Participation in this study is voluntary. You can refuse to answer any questions at any time and can withdraw without any penalty. Return of the questionnaire is deemed consent to participate in the research study.

Contact information

The Principal Investigator on this student research study is Samuel T. Ingram and may be contacted at 864-656-3447 for more information on this study. If you have any questions regarding your rights as a research participant, you may contact the Office of Research Compliance at 864-656-6460.

Thank you,

Appendix B

Viewing Orientation

Orientation of Photos for viewing and their corresponding dot structures

A-Conventional (AM)
B-Alternative (XM) at 340
C-Alternative (XM) at 240

Photo		Screening		Viewing Order
Iguana		B A C		1 2 3
Cougar		C B A		1 2 3
Leaf		A C B		1 2 3
Spools		A B C		1 2 3
Hallway		C A B		1 2 3

Appendix C

Survey Instrument

Please complete the demographic data. This information will be used only to determine your experience in the printing field and qualifying the differences between groups of people involved in this study.

1. **Do you work in the printing field?**

   Yes **No, go to question #4**

2. **Do you work in the office or the shop?**

   Office **Shop**

3. **How many years have you been in printing?**

4. **What is your title?**

5. **I am completing this study as an;**

   Educator **Student** **Printer**

6. **Gender; Circle one:**

   Male or Female

7. **Age; Circle one:**

   18 to 25 yrs old
   26 to 35 yrs old
   36 to 45 yrs old
   46 to 55 yrs old
   56 to 65 yrs old
   66 and older

8. **Vision; Circle one:**

   Corrected **Uncorrected**

Evaluation of Halftones
Based on the following terms, which photo (1, 2, or 3) would you rank as having the highest quality? Circle your choice.

Iguana

Color Balance	1	2	3	No difference
Saturation	1	2	3	No difference
Contrast	1	2	3	No difference
Sharpness	1	2	3	No difference
Detail	1	2	3	No difference

Cougar

Color Balance	1	2	3	No difference
Saturation	1	2	3	No difference
Contrast	1	2	3	No difference
Sharpness	1	2	3	No difference
Detail	1	2	3	No difference

Leaf

Color Balance	1	2	3	No difference
Saturation	1	2	3	No difference
Contrast	1	2	3	No difference
Sharpness	1	2	3	No difference
Detail	1	2	3	No difference

Spools

Color Balance	1	2	3	No difference
Saturation	1	2	3	No difference
Contrast	1	2	3	No difference
Sharpness	1	2	3	No difference
Detail	1	2	3	No difference

Hallway-Grayscale

Color Balance	1	2	3	No difference
Saturation	1	2	3	No difference
Contrast	1	2	3	No difference
Sharpness	1	2	3	No difference
Detail	1	2	3	No difference

Appendix D

Location and Number of Participants

Location	Date	Category of Viewer	# of Participants
S. Friendswood Dr.	3/16/07	Other	3
Gonsoulin Dr.	3/17/07	Other	2
South West Precision Printers	6/21/07	Printers	24
C. E. King HS	5/9/07	Educators (non-print)	50
C. E. King HS	5/23/07	Educators (non-print)	23
Minuteman Press	6/22/07	Printers	5
Houston Desktop Graphics	6/22/07	PrePress	1
North Carolina A&T Graphics	5/1/07	Print Educators	7
Cal Poly	1/10/06	Print Educators	5
University of Houston Press	6/25/07	University Print Shop	7
University of Houston Graphics	6/22/07	Graphics Dept. Shop	3
		Total	140

Appendix E

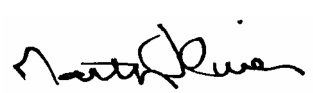
Evaluation Procedures

Thank you for your participation in my doctoral dissertation study. Please follow the directions in the order written. Failure to follow the directions may negate the information you have provided.

1. Open the envelope with the back facing up. This page should be the first page.
2. Read the: Informational Letter Describing Your Participation in a Doctoral Dissertation Study.
3. Complete the demographic data that starts with question number 1; Do you work in the printing field?
4. Remove the stack of printed photographs. Remove the rubber band. Lay out the Iguana photos, in order from left to right with the number sequence; 1, 2, 3.
5. Begin to complete the page entitled, Evaluation of Halftones, circling the number which represents the print with the highest quality in each of the five areas beginning with color balance.
6. Refer to the definitions on the page entitled; Definitions, for accepted explanations of the terms of evaluation.
7. Then, lay out the Cougar photos, in order from left to right with the number sequence; 1, 2, 3.
8. Continue to complete the page entitled, Evaluation of Halftones, circling the number which represents the print with the highest quality in each of the five areas beginning with color balance.
9. Continue until you have rated all five prints.
10. Put everything into the envelope addressed to me and mail the envelope back to me. Postage has been paid.

Thank you again for your participation.

Sincerely,



Garth Oliver

Appendix F

Definitions of Terms to Evaluate Quality

The following is a list of the terms, developed through research and piloted at the monthly Houston Print Managers Association meeting, that are used in this study to evaluate the quality of printed halftones.

Color Balance- The colors look like they are supposed to look. Greens are green, blues are blue, etc.

Saturation- The intensity or vibrancy of the color represented. The more saturated the color, the further away it is from gray. The less saturated, the closer it is to gray or white.

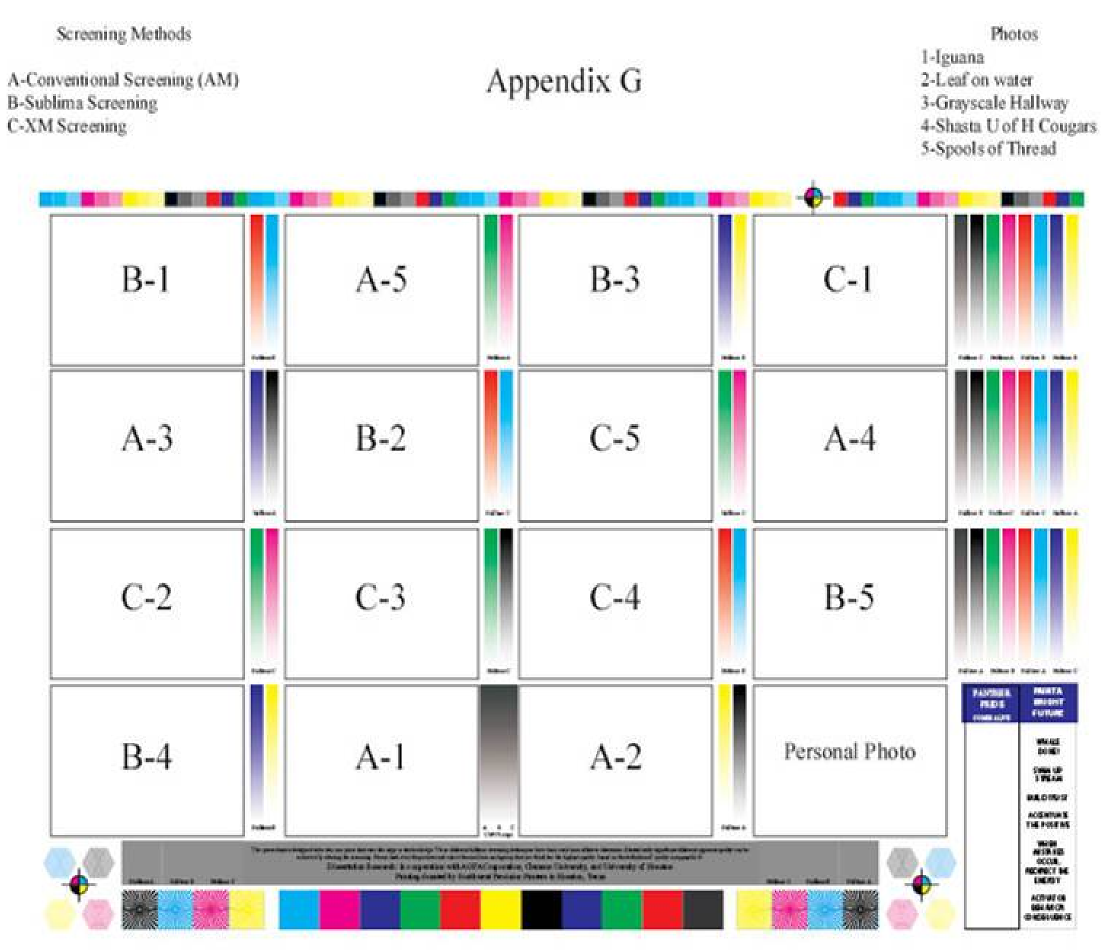
Contrast- The difference between the dark and the light areas of the photo that provide the subtle changes in tone. These slight changes provide the detail that keeps the picture from looking like one big blob of ink.

Sharpness- Clarity and focus of the photo. The sharper the picture, the more crisp it looks. The less sharpness in the picture would show a softer focus. Don't be confused with selective focus as in the picture of the Iguana. There are parts of that photo that are supposed to be out of focus.

Detail- The difference in tone that provide the shapes, curves, shadows, and tiny significant parts of the photo. Detail allows you to see these subtle differences in the picture.

Appendix G

Scaled Down Representation of the Press Sheet



Appendix H

Collected Data

Non Printers	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Iguana	1	1	1	1	1
	1	1	1	1	1
Choices are					
represented	1	1	1	1	1
by numbers 1, 2, 3, or 4	1	1	1	1	1
	1	1	1	1	1
HA = 2	1	1	1	1	1
HB = 1	1	1	1	1	1
HC = 3	1	1	1	1	1
No Difference = 4	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	2	1	1
	1	1	2	1	1
	1	1	2	1	1
	1	1	2	1	2
	1	1	2	1	2
	1	1	2	1	2
	1	2	2	1	2
	1	2	2	1	2
	1	2	2	1	2
	2	2	2	1	2
	2	2	2	2	2
	2	2	2	2	3
	2	2	3	2	3
	2	2	3	2	3
	2	2	3	2	3
	3	2	3	2	3
	3	2	3	2	3
	3	3	3	2	3
	3	3	3	2	3
	3	3	3	2	3
	3	3	4	2	3
	3	4	4	2	4
	4	4	4	2	4
	4	4	4	3	4
	4	4	4	3	4
	4	4	4	3	4
	4	4	4	3	4

	4	4	4	3	4
	4	4	4	3	4
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	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4

Non Printers	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Cougar	1	1	1	1	1
	1	1	1	1	1
Choices are					
represented	1	1	1	1	1
by numbers 1, 2, 3, or 4	1	1	1	1	1
	1	1	1	1	1
HA = 3	1	1	1	1	1
HB = 2	1	1	1	1	1
HC = 1	1	1	1	1	1
No Difference = 4	1	1	1	1	1
	1	1	1	1	1

1	2	1	1	1
2	2	1	1	1
2	2	1	2	1
2	2	1	2	2
2	2	2	2	2
2	2	2	2	2
2	2	2	2	2
2	2	2	2	2
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2	3	2	2	2
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4	4	4	4	4

Non Printers	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Leaf	1	1	1	1	1
	1	1	1	1	1
Choices are					
represented	1	1	1	1	1
by numbers 1, 2, 3, or 4	1	1	1	1	1
	1	1	1	1	1
HA = 1	1	1	1	1	1
HB = 3	1	1	1	1	1
HC = 2	1	1	1	1	1
No Difference = 4	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	2	1	1	1
	1	2	1	2	1
	1	2	1	2	1
	1	2	1	2	1
	1	2	2	2	2
	1	2	2	2	2
	1	2	2	2	2
	2	2	2	2	2
	2	2	2	2	2
	2	2	2	2	2

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2	2	2	2	2
2	2	2	2	2
2	2	2	2	3
2	2	2	2	3
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2	3	2	3	3
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4	4	4	4	4

Non Printers	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Spools	1	1	1	1	1
	1	1	1	1	1
Choices are					
represented	1	1	1	1	1
by numbers 1, 2, 3, or 4	1	1	1	1	1
	1	1	1	1	1
HA = 1	1	1	1	1	1
HB = 2	1	1	1	1	1
HC = 3	1	1	1	1	1
No Difference = 4	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	2	1	1	1
	1	2	1	1	1
	1	2	1	1	1
	1	2	2	1	1
	2	2	2	2	1
	2	2	2	2	2
	2	2	2	2	2
	2	2	2	2	2
	2	2	2	2	2
	2	2	2	2	2
	2	2	2	2	2
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	2	3	2	2	3
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4	4	4	4	4

Non Printers	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Hallway	1	1	1	1	1
	1	1	1	1	1
Choices are represented	1	1	1	1	1
by numbers 1, 2, 3, or 4	1	1	1	1	1
	1	1	1	1	1
HA = 2	1	1	1	1	1
HB = 3	1	1	1	1	1
HC = 1	2	1	1	1	1
No Difference = 4	2	1	1	1	2
	2	2	1	1	2
	2	2	1	2	2
	2	2	1	2	2
	2	2	2	2	2

2	2	2	2	2
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4	4	4	4	4
4	4	4	4	4
4	4	4	4	4

Printers	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Iguana	1	0	1	1	1
	1	0	1	1	1
Choices are represented	1	0	1	1	1
by numbers 1, 2, 3, or 4	1	0	1	1	1
	1	0	1	1	1
HA = 2	1	1	1	1	1
HB = 1	1	1	1	1	1
HC = 3	1	1	1	1	1
No Difference = 4	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	2	1	1
	1	1	2	1	1
	1	1	2	1	1
	1	1	3	2	2
	1	1	3	2	3
	1	1	3	2	3
	2	1	3	2	3
	2	1	3	3	3
	2	1	3	3	3
	2	2	3	3	3
	2	3	3	3	3
	2	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3

	3	3	4	3	3
	3	3	4	3	3
	4	3	4	3	4
	4	3	4	3	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
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	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4

Printers	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Cougar	1	0	1	1	1
	1	0	1	1	1
Choices are represented	1	0	1	1	1
by numbers 1, 2, 3, or 4	1	0	1	1	1
	1	0	1	1	1
HA = 3	1	1	1	2	1
HB = 2	1	1	1	2	2
HC = 1	1	1	1	2	2
No Difference = 4	1	1	1	2	2
	2	1	2	2	2
	2	1	2	2	2
	2	2	2	2	2
	2	2	2	2	2
	2	2	2	2	2
	2	2	2	2	2
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2	2	2	2	3
2	2	2	2	3
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3	2	3	3	3
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3	3	3	4	4
4	3	3	4	4
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4	3	4	4	4
4	4	4	4	4
4	4	4	4	4
4	4	4	4	4
4	4	4	4	4
4	4	4	4	4

Printers	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Leaf	1	0	1	1	1
	1	0	1	1	1
Choices are represented	1	0	1	1	1
by numbers 1, 2, 3, or 4	1	0	1	1	1
	1	0	1	1	1
HA = 1	1	1	1	1	1
HB = 3	1	1	1	1	1
HC = 2	1	1	1	1	1
No Difference = 4	1	1	1	1	2
	1	1	1	1	2
	1	1	2	1	2
	1	1	2	1	2
	1	1	2	1	2
	1	1	2	1	2
	1	1	2	1	2
	1	1	2	2	2
	2	1	2	2	2
	2	1	2	2	2
	2	1	2	2	2
	2	2	2	2	2
	2	2	2	2	3
	2	2	2	2	3

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2	2	3	3	3
2	2	3	3	3
2	2	3	3	3
3	2	3	3	3
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4	4	4	4	4
4	4	4	4	4
4	4	4	4	4
4	4	4	4	4
4	4	4	4	4

Printers	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Spools	1	0	1	1	1
	1	0	1	1	1
Choices are represented by numbers 1, 2, 3, or 4	1	0	1	1	1
	1	0	1	1	1
	1	0	1	1	1
HA = 1	1	1	1	1	1
HB = 2	1	1	1	1	1
HC = 3	1	1	1	1	1
No Difference = 4	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	1	1	1	1
	1	2	1	1	2
	1	2	2	2	2
	2	2	2	2	2
	2	2	2	2	2
	2	2	2	2	2
	2	2	2	2	2

2	2	2	2	2
2	3	2	2	2
2	3	2	2	2
2	3	2	3	2
3	3	2	3	3
3	3	2	3	3
3	3	2	3	3
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4	4	4	4	4
4	4	4	4	4
4	4	4	4	4

Printers	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Hallway	1	0	1	1	1
	1	0	1	1	1
Choices are represented	1	0	1	1	1
by numbers 1, 2, 3, or 4	1	0	1	1	1
	1	0	1	1	1
HA = 2	2	1	1	1	1
HB = 3	2	1	1	1	1
HC = 1	2	1	1	1	1
No Difference = 4	2	1	1	1	2
	2	1	1	1	2
	2	1	1	2	2
	2	1	2	2	2
	2	1	2	2	2
	2	1	2	2	2

2	2	2	2	2
2	2	2	2	2
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4	4	4	4	4
4	4	4	4	4
4	4	4	4	4

Corrected Vision	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Iguana	1	1	1	1	1
	1	1	1	1	1
Choices are					
represented	1	1	1	1	1
by numbers 1, 2, 3, or 4	1	1	1	1	1
	1	1	1	1	1
HA = 2	1	1	1	1	1
HB = 1	1	1	1	1	1
HC = 3	1	1	3	1	1
No Difference = 4	1	1	3	2	1
	1	1	3	3	1
	1	3	3	3	3

	2	3	3	3	3
	2	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3
	3	3	4	3	3
	4	3	4	4	3
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4

Uncorrected vision	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Iguana	1	1	1	1	1
	1	1	2	1	2
Choices are					
represented	1	1	3	1	3
by numbers 1, 2, 3, or 4	1	1	3	2	3
	2	1	3	2	3
HA = 2	2	3	3	3	3
HB = 1	3	3	3	3	3
HC = 3	3	3	3	3	3
No Difference = 4	3	3	3	3	3
	3	3	4	3	3
	3	4	4	3	4
	4	4	4	3	4
	4	4	4	3	4
	4	4	4	4	4

Male	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Iguana	1	1	1	1	1
	1	1	1	1	1
Choices are					
represented	1	1	1	1	1
by numbers 1, 2, 3, or					
4	1	1	1	1	1
	1	1	1	1	1
HA = 2	1	1	1	1	1
HB = 1	1	1	2	1	2
HC = 3	1	1	3	1	3
No Difference = 4	1	1	3	2	3
	1	1	3	2	3
	2	3	3	3	3
	2	3	3	3	3

2	3	3	3	3
3	3	3	3	3
3	3	3	3	3
3	3	3	3	3
3	3	3	3	3
3	3	4	3	3
3	4	4	3	3
4	4	4	3	4
4	4	4	3	4
4	4	4	4	4
4	4	4	4	4
4	4	4	4	4
4	4	4	4	4
4	4	4	4	4
4	4	4	4	4
4	4	4	4	4

Female	**Color Balance**	**Saturation**	**Contrast**	**Sharpness**	**Detail**
Iguana	1	1	1	1	1
	1	1	1	1	1
Choices are represented	1	1	3	1	1
by numbers 1, 2, 3, or 4	1	1	3	2	1
	1	1	3	3	1
HA = 2	2	3	3	3	3
HB = 1	3	3	3	3	3
HC = 3	3	3	4	3	3
No Difference = 4	4	3	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4
	4	4	4	4	4

Paper used for the Press run

Paper at 0%

	L	**a**	**b**
Sample 1	94.88	0.99	-2.9
Sample 2	94.88	0.83	-3.12
Sample 3	94.66	0.93	-3.12
Sample 4	94.92	0.76	-3
Sample 5	94.29	1.31	-3.24
Sample 6	94.41	0.82	-2.98
Sample 7	94.31	1.3	-3.22
Sample 8	94.83	1.22	-3.16
Sample 9	94.87	0.82	-3.12
Sample 10	94.6	1.24	-3.24
Sample 11	94.68	1.2	-3.13
Sample 12	94.92	1.18	-3.19
Sample 13	94.89	1.17	-3.23
Sample 14	94.66	1.31	-3.3
Sample 15	95	0.92	-3.14
Sample 16	94.7	1.24	-3.23
Sample 17	94.56	1.24	-3.2
Sample 18	94.9	1.28	-3.17
Sample 19	94.66	1.26	-3.25
Sample 20	94.46	1.24	-3.16
Sample 21	94.74	1.16	-3.17

Sample 22	94.59	1.2	-3.12	Sample 27	94.34	1.19	-3.16
Sample 23	94.79	1.17	-3.14	Sample 28	93.93	1.22	-3.18
Sample 24	94.94	1.19	-3.15	Sample 29	93.87	1.07	-3.16
Sample 25	94.76	1.18	-3.22	Sample 30	94.92	0.95	-3.31
Sample 26	94.73	1.49	-3.26				

Two reads in the Same Place

Measurements were taken two times in the same place to determine accuracy of the Spectrophotometer readings.

Delta 2 reads

0.17	0.2	0.39
0.16	0.1	0.17
0.11	0.18	0.21
0.14	0.14	0.14
0.16	0.21	0.19
0.05	0.22	0.24
0.19	0.16	0.13
0.11	0.09	0.21
0.08	0.17	0.09
0.15	0.1	0.1
0.21	0.25	0.06
0.16	0.26	0.14
0.15	0.12	0.17
0.16	0.09	0.08
0.27	0.11	0.21
0.14	0.18	0.17
0.24	0.16	0.07
0.22	0.02	0.14
0.19	0.14	0.14
	0.13	0.13
	0.19	

Solid Ink Densities and Lab Values

All scales Lab Values at 100%

	SID	**L**	**a**	**b**
3-color black	1.2	34.65	11.83	0.69
Black	1.86	13.22	1.69	0.8
Green	1.13	55.14	-61.65	20.06
Magenta	1.41	48.98	72.3	-5.72
Red	1.42	48.78	66.64	41.97
Cyan	1.24	58.35	-34.49	-46.94
Blue	1.48	26.64	32.78	-39.55
Yellow	0.86	90.19	-7.95	83.8

Density and Dot Gain

Density			Dot %			Dot Gain		
HA	HB	HC	HA	HB	HC	HA	HB	HC
0.41	0.44	0.41	62	65	62	12	15	12
0.4	0.43	0.4	61	64	61	11	14	11
0.41	0.44	0.4	62	65	62	12	15	12
0.4	0.42	0.4	61	64	61	11	14	11
0.4	0.43	0.4	61	64	61	11	14	12
0.4	0.44	0.4	61	64	61	11	14	11
0.4	0.43	0.4	61	64	61	11	14	12
0.4	0.43	0.4	61	64	61	11	14	12
0.4	0.44	0.41	61	65	61	11	15	12
0.41	0.43	0.41	62	64	62	12	14	12
0.4	0.42	0.4	61	64	61	11	14	11
0.4	0.43	0.4	61	64	61	11	14	11
0.4	0.43	0.4	62	64	62	12	14	11
0.4	0.43	0.4	61	64	61	11	14	12
0.4	0.43	0.4	62	64	62	12	14	11
0.4	0.43	0.4	61	64	61	11	14	12
0.4	0.43	0.4	61	64	61	11	14	11
0.4	0.43	0.4	62	64	62	12	14	12
0.4	0.43	0.4	61	64	61	11	14	11
0.4	0.43	0.4	61	64	61	11	14	11
0.4	0.43	0.4	62	64	62	12	14	11
0.41	0.43	0.4	62	64	62	12	14	12
0.4	0.44	0.4	62	65	62	12	15	11
0.41	0.44	0.41	62	65	62	12	15	12
0.4	0.43	0.4	62	64	62	12	14	11
0.41	0.44	0.41	62	65	62	12	15	12
0.41	0.44	0.41	62	65	62	12	15	12
0.4	0.44	0.41	61	64	61	11	14	12
0.41	0.43	0.4	62	64	62	12	14	11
0.4	0.43	0.41	61	64	61	11	14	12
0.41	0.44	0.41	62	65	62	12	15	12
0.41	0.44	0.4	62	65	62	12	15	12
0.4	0.43	0.4	61	64	61	11	14	11
0.4	0.43	0.4	62	64	62	12	14	12
0.4	0.43	0.4	62	64	62	12	14	11
0.4	0.43	0.4	61	64	61	11	14	12
0.4	0.43	0.4	62	64	62	12	14	12
0.41	0.44	0.41	62	64	62	12	14	12
0.4	0.43	0.4	61	64	61	11	14	12
0.4	0.42	0.4	61	63	61	11	13	11

Print Contrast

Print Contrast

3 color K			**4 color K**			**Magenta**		
HA	HB	HC	HA	HB	HC	HA	HB	HC
26	21	24	53	53	54	38	40	40
24	21	23	52	52	54	37	39	40
25	21	22	54	51	53	36	38	38
26	21	22	53	49	54	38	37	40
26	21	22	52	50	53	39	37	39
25	19	21	54	51	54	36	38	38
26	19	23	54	50	54	38	38	40
25	19	22	54	51	54	38	38	40
25	20	21	53	50	54	38	39	37
24	21	22	54	50	54	37	39	40

Red			**Cyan**			**Yellow**		
HA	HB	HC	HA	HB	HC	HA	HB	HC
41	40	30	42	33	41	35	30	34
32	36	31	36	35	37	35	28	33
41	35	27	42	33	38	35	28	34
35	31	27	38	30	35	35	29	35
38	36	29	40	31	37	34	27	35
39	35	26	41	30	35	34	27	34
34	33	25	37	28	37	34	28	34
34	30	31	36	34	32	34	28	34
32	34	24	36	26	35	34	26	34
36	34	35	36	38	37	35	27	34

Tone Scales

Red at 97%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
48.65	48.03	47.67	66.96	68.19	69.97	42.06	44.85	42.79
48.73	48.26	47.98	69.07	67.64	68.72	42.79	44.75	43.52
48.63	48.15	48.27	66.73	67.75	67.69	41.83	44.21	42.5
48.69	48.11	47.84	66.72	67.89	68.62	41.7	44.83	43.04
48.61	48.04	48.31	67.02	67.95	67.64	41.83	44.58	42.55
48.59	47.94	48.18	66.99	68.16	68	42	44.27	43.4
48.66	47.93	47.8	66.7	68.32	68.77	41.87	43.95	43.02
48.94	48.14	48.09	66.42	67.87	68.02	42.08	44.82	43.52
48.91	48.18	48.06	66.52	67.84	68.12	42.44	44.58	43.05
48.79	48.18	47.88	66.73	67.84	68.62	42.14	44.79	43.27

48.73	48.35	47.91	68.62	67.71	68.49	43.27	44.26	42.87
48.91	48.04	48.09	66.64	68.15	68.11	42.22	44.29	43.23
48.92	47.81	48.01	66.56	68.59	68.2	42.41	44.52	42.59
48.69	48.1	47.99	66.89	67.96	68.31	41.8	45.19	43.04
48.81	48.09	47.74	66.48	67.86	68.68	42.21	44.61	42.77
48.59	48.46	48.05	67.11	67.01	68.27	42.01	45.09	43.61
48.53	47.96	48.03	67.12	67.98	68.03	41.98	44.89	43.06
48.64	48.16	48.26	66.95	67.58	67.53	42.07	44.6	42.98
48.72	48.07	48.19	66.47	67.8	67.53	42.2	44.48	43.05
48.81	47.73	48.28	66.32	68.54	67.36	41.8	44.74	43.14

Blue at 97%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
25.92	24.92	25.9	35.38	33.31	34.42	-38.31	-39.86	-39.38
25.78	24.95	26.05	35.39	34.55	34.28	-38.54	-39.11	-39.43
26.12	24.73	25.5	34.59	33.17	34.54	-38.66	-39.93	-39.11
26.03	24.87	25.31	34.23	33.34	33.26	-38.97	-39.9	-39.79
25.39	25.1	25.72	33.93	33.5	33.12	-39.79	-39.49	-39.41
25.96	25.1	25.99	34.35	33.62	33.29	-39.27	-39.33	-39.44
26.12	25.01	26.07	34.74	32.64	33.69	-38.52	-40	-39.18
25.97	25.32	26.04	35.02	32.35	31.5	-38.53	-40.12	-40.11
25.13	25.21	25.68	33.12	33.36	32.15	-39.84	-40.07	-40.32
25.39	25.54	25.61	33.51	32.3	34.16	-39.52	-40.3	-39.18

Green at 97%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
57.79	59.88	58.94	-55.35	-52.7	-53.03	24.44	24.03	23.88
57.03	58.87	58.79	-56.69	-54.35	-53.7	21.99	24.96	24.42
56.01	59.16	59.08	-57.35	-53.72	-53.68	19.85	24.47	24.59
56.38	58.59	59.1	-56.64	-53.42	-53.39	20.04	21.61	24.56
57.2	58.94	58.35	-55.79	-53.25	-53.51	21.21	22.8	22.19
56.74	58.94	58.51	-57.17	-54.46	-53.84	21.05	23.47	23.75
56.59	58.86	59.44	-55.9	-54.46	-52.98	19.79	23.66	25.07
56.99	57.15	58.89	-55.31	-56.27	-53.59	20.5	20.4	25.15
57.33	57.93	58.23	-55.11	-54.92	-53.58	21.83	21.67	22.25
57.62	58.24	58.94	-55.33	-55.19	-53.09	22.11	22.31	23.99

3-color Black at 97%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
37.29	35.13	36.87	11.64	13.36	10.24	1.7	3.31	4.4

37.28	35.62	37.8	10.72	12.85	10.05	1.4	3.74	4.69
37.44	36.48	37.41	10.3	13.06	10	1.49	4.1	4.01
37.29	36.25	37.01	10.24	11.59	9.93	0.73	3.8	3.95
37.6	35.76	37.53	10.61	11.1	9.95	1.38	2.52	4.19
37.24	35.97	37.07	10.82	12.14	10.08	1.34	3.44	3.65
37.34	36.2	37.25	10.23	12.95	9.24	1.21	3.63	3.31
37.49	35.5	37.17	10.12	12.16	9.75	0.58	3.75	3.8
36.93	35.51	36.75	9.77	11.88	10.09	1.1	2.56	4.14
37.12	35.48	36.75	9.99	13.01	10.15	1.5	2.9	3.97

4-color Black at 50%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
64.76	62.95	64.62	-2.27	-1.61	-2.08	-1.07	-1.24	-0.52
65.22	63.62	65.24	-2.47	-2.32	-2.25	-1.41	-1.74	-0.78
64.87	63.18	65.11	-2.44	-2.36	-1.91	-1.79	-1.77	-1.1
65.36	63.7	65.71	-2.09	-1.89	-2.1	-1.12	-1.04	-0.3
65.46	63.74	65.09	-2.22	-1.91	-1.97	-1.42	-1.32	-0.5
65.19	63.61	65.11	-2.3	-2.27	-2.21	-1.57	-1.57	-0.88
64.88	63.1	64.99	-2.3	-2.29	-2.46	-1.68	-1.54	-0.81
65.27	63.52	65.39	-2.35	-2.34	-2.22	-1.45	-1.48	-0.75
65.25	63.35	65.25	-2.55	-2.37	-2.29	-1.63	-1.38	-0.4
65.05	63.59	65.34	-2.48	-2.48	-2.32	-1.53	-1.25	-0.63
65.26	63.77	65.05	-2.35	-2.2	-2.2	-1.68	-1.47	-0.54
65.63	63.68	65.68	-2.04	-2.12	-2.07	-0.49	-1.25	-0.41
64.91	63.38	65.47	-2.41	-2.39	-2.23	-1.47	-1.45	-0.43
65.72	63.76	65.36	-2.54	-2.39	-2.52	-1.59	-1.56	-0.8
65.37	63.5	65.33	-2.45	-2.27	-2.25	-1.43	-1.43	-1.03
65.62	63.67	65.53	-2.23	-2.03	-1.91	-0.84	-0.99	-1.13
65.44	63.67	65.28	-2.29	-2.07	-1.95	-1.3	-1.15	-0.77
65.49	63.4	65.27	-2.33	-2.2	-2.42	-1.34	-1.43	-0.79
65.64	63.66	65.55	-2.28	-2.17	-1.84	-1.36	-1.59	-0.63
65.79	64.02	65.6	-2.06	-1.91	-2.04	-1.1	-1.21	-0.71
65.65	63.7	65.5	-2.2	-1.88	-1.98	-1.12	-1.37	-0.77
65.58	63.74	65.6	-1.98	-1.84	-1.9	-0.77	-1.37	-0.97
65.3	63.53	65.29	-2.14	-1.95	-1.88	-1.53	-1.25	-0.59
65.28	63.4	65.26	-2.23	-1.85	-1.78	-1	-0.98	-0.81
65.58	63.86	65.45	-2.17	-1.91	-1.98	-1.29	-1.01	-0.67
65.25	63.23	64.84	-2.15	-1.84	-2.09	-1.51	-1.43	-0.85
65.33	63.71	65.16	-2.34	-1.81	-1.9	-1.11	-1.1	-1.01
65.31	63.59	65.15	-1.89	-1.75	-1.74	-1.04	-0.95	-0.67
65.22	63.39	65.18	-2.04	-1.82	-1.86	-0.99	-0.76	-0.46
65.58	63.44	65.49	-2.33	-2.17	-2.11	-1.03	-1.11	-0.82
65.4	63.42	65.08	-1.93	-1.75	-1.86	-1.2	-1.22	-0.8
65.28	63.44	64.02	-2.2	-1.98	-1.68	-1.39	-1.5	-0.51
65.59	63.81	65.34	-2.17	-1.87	-1.93	-1.32	-1.21	-0.73

65.45	63.38	65.29	-2.02	-1.87	-1.96	-1.43	-1.46	-0.9
65.65	63.75	65.39	-2.38	-2.34	-2.12	-1.09	-1.14	-0.86
65.9	63.83	65.61	-2.08	-1.54	-2.02	-0.88	-0.84	-0.73
65.64	63.53	65.33	-2.05	-1.9	-1.8	-1.04	-0.91	-0.66
65.08	63.28	65.11	-2.34	-2.06	-1.99	-1.23	-1.42	-0.5
65.92	63.77	65.56	-2.17	-2.23	-2.08	-0.87	-1	-0.54
65.8	64.06	65.45	-2.08	-1.9	-2.15	-1.06	-0.99	-0.33

Red at 50%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
77.29	73.98	75.88	18.61	23.81	20.69	18.29	19.3	18.81
76.67	74.73	76.26	19.38	23.21	20.19	18.67	19.41	19.4
76.76	75.99	75.95	19.59	20.86	20.7	18.73	19.09	19.3
76.94	76.11	75.68	19.28	20.67	21.02	18.92	19.37	19.24
77.15	76.09	76.02	18.86	20.6	20.54	18.38	18.91	19.19
77.57	75.78	76.11	18.48	20.92	20.52	18.03	19.69	18.86
77.43	75.8	76.53	18.77	20.83	19.96	18.3	19.49	18.49
77.32	75.01	76.07	18.8	22.21	20.72	18.32	19.28	18.47
77.3	75.07	75.9	18.92	22.34	20.84	18.53	19.92	19.04
77.64	75.61	76.32	18.48	21.43	20.34	18.3	19.12	18.31

Blue at 50%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
65.99	65.61	66.53	10.77	13.97	10.12	-20.48	-20.57	-20.31
67.02	65.46	67.85	10.13	12.95	10.38	-19.97	-20.94	-19.42
66.82	65.92	66.98	11.11	11.97	10.52	-19.67	-20.74	-20.11
66.15	66.55	66.89	11.28	11.49	10.49	-20.12	-20.61	-20.09
66.83	65.89	67.27	11.23	11.87	10.11	-19.71	-20.65	-19.72
65.9	66.7	67.66	10.81	12.02	9.93	-20.43	-20.17	-19.53
66.5	66.94	67.54	10.01	12.18	10.01	-20.35	-19.81	-19.78
66.83	66.02	67.7	10.65	12.47	9.31	-19.83	-20.65	-20.05
66	65.82	67.97	10.62	12.15	9.47	-20.63	-20.77	-19.68
66.22	66.79	67.93	10.83	10.95	9.52	-20.26	-20.51	-19.28

Green at 50%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
81.82	79.86	80.32	-15.72	-17.99	-17.57	10.56	10.7	11.04
81.3	80.41	80.28	-15.94	-17.61	-17.12	9.82	10.94	10.16
81.43	80.22	80.18	-16.22	-18.09	-17.33	11.41	11.54	11.03
81.05	79.66	80.92	-16.3	-18.36	-16.89	10.66	11.08	11.64
81.2	80.48	80.94	-15.8	-17.55	-16.99	10.01	10.86	11.78

81.44	80.24	80.44	-16.11	-17.62	-16.83	10.62	10.51	10.26
82.12	80.07	80.84	-15.45	-17.51	-16.48	11.18	9.94	9.6
81.15	79.86	81.35	-16.34	-17.68	-16.29	10.7	9.43	10.34
80.7	80.29	80.77	-16.51	-17.85	-16.97	10.15	10.82	10.12
82.04	80.19	80.56	-15.6	-17.71	-16.81	10.42	10.73	9.84

3- color Black at 50%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
69.72	67.68	70.57	2.46	3.3	3.56	1.59	2.21	1.96
70.34	68.6	70.39	2.81	2.63	3.17	1.68	1.84	1.64
70.38	68.26	71.34	2.8	3.28	3.19	1.78	2.08	2.29
69.51	68.05	71.29	2.39	3.81	2.74	1.56	2.66	2.15
70.5	68.95	71.03	2.6	3.56	2.61	1.99	2.81	2.01
70.39	68.45	70.4	2.63	3.18	2.92	1.69	1.73	2.37
70.29	68.9	70.9	2.51	2.94	2.95	1.21	1.8	2.66
70.65	68.55	71.24	2.31	3.84	3.37	1.7	2.45	1.93
70.64	68.47	70.59	2.39	3.27	3.22	2.02	1.62	1.57
70.88	67.76	71.63	2.38	3.33	3.1	1.91	1.68	2.03

Red at 10%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
91.83	92.96	92.37	3.52	2.62	2.97	1.29	0.1	0.83
92.08	92.72	92.32	3.3	2.63	3.02	1.28	0.25	0.62
91.91	92.78	92.32	3.36	2.49	3	1.03	-0.02	0.6
91.9	92.77	92.35	3.32	2.57	2.98	1.15	-0.13	0.71
91.97	92.5	92.54	3.31	2.8	2.79	1.15	0.09	0.41
91.84	92.48	92.28	3.35	2.82	3.14	1.24	0.3	0.7
91.91	92.56	92.11	3.33	2.79	3.32	1.41	0.16	0.76
91.93	92.42	92.39	3.35	2.75	3	1.39	0.28	0.69
91.96	92.64	92.3	3.35	2.82	3.08	1.29	0.09	0.62
91.98	92.71	92.39	3.3	2.75	3.04	1.21	0.05	0.81

Blue at 10%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
89.51	91.2	91.37	2.65	2.35	2.08	-6.46	-5.58	-5.45
89.71	91.39	91.81	2.59	2.08	1.97	-6.7	-5.41	-5.11
89.32	91.65	91.24	2.44	2.12	2.11	-6.92	-5.09	-5.51
89.13	91.18	91.21	2.27	2.18	1.96	-7.11	-5.53	-5.59
89.39	91.01	91.16	2.33	2.03	1.96	-6.84	-5.62	-5.82
89.26	90.98	90.98	2.45	2.06	2.29	-6.92	-5.7	-5.59
89.04	90.99	90.99	2.64	2.28	2.16	-7.07	-5.63	-5.76

89.12	91.08	91.18	2.36	2.09	1.95	-7.11	-5.59	-5.61
89.41	90.8	91.48	2.57	2.08	1.87	-6.72	-5.95	-5.51
89.77	91.18	91.73	2.51	1.88	1.96	-6.55	-5.62	-5.14

Green at 10%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
92.81	93.8	93.29	-2.6	-1.56	-1.95	0.25	-0.58	-0.05
92.92	93.54	93.35	-2.42	-1.82	-1.82	0.03	-0.19	-0.36
92.92	93.27	93.07	-2.29	-1.9	-2.12	0.22	-0.43	-0.56
92.82	93.26	93.13	-2.34	-1.91	-2.17	-0.07	-0.61	-0.33
92.6	93.45	93.28	-2.44	-1.98	-1.98	-0.18	-0.34	-0.23
92.71	93.56	93.17	-2.47	-1.84	-2.08	0.14	-0.16	-0.44
92.87	93.2	93.08	-2.39	-2.23	-2.27	0.13	-0.19	-0.3
92.74	93.05	93.14	-2.53	-2.26	-2.28	0.15	-0.4	-0.18
92.59	93.3	93.22	-2.72	-2.12	-2.13	-0.15	-0.05	0.07
93.61	93.31	92.85	-1.71	-1.89	-2.47	-0.29	-0.27	-0.08

3-color Black at 10%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
90.98	91.78	92.21	1.19	1.02	0.98	-1.19	-1.36	-1.71
90.91	91.48	91.83	1.15	1.01	1.01	-1.17	-1.74	-1.56
90.59	91.02	91.85	1.06	0.85	1.03	-1.25	-1.96	-1.54
90.48	91.21	91.91	0.95	0.98	0.97	-1.42	-1.72	-1.87
90.7	91.28	91.99	1.14	0.92	0.81	-1.28	-1.65	-1.94
90.83	91.28	91.83	1.17	0.92	0.94	-1.01	-1.82	-1.84
90.71	91.32	91.95	1.05	1.01	1.02	-1.23	-2.04	-1.7
90.35	91.13	92.2	0.92	0.93	0.85	-1.29	-1.64	-1.87
90.54	91.31	91.72	1.13	1.09	0.79	-1.19	-1.5	-2.07
90.69	91.52	91.59	1.09	1.02	0.85	-0.91	-1.74	-1.77

Red at 5%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
93.33	93.94	93.61	2.31	1.71	1.87	0.19	-1.16	-0.87
92.93	94.04	93.9	2.37	1.38	1.51	0.24	-1.45	-1.01
92.9	94.04	93.96	2.43	1.34	1.49	0.23	-1.63	-1.28
93.06	93.61	93.84	2.22	1.56	1.53	0.1	-1.23	-1.18
92.63	93.58	93.75	2.4	1.54	1.67	0.1	-1.31	-1.13
92.82	93.77	93.98	2.44	1.47	1.5	0	-1.26	-1.14
92.66	93.42	93.76	2.4	1.75	1.71	0.34	-1.06	-1.14
92.52	93.58	93.56	2.65	1.71	1.73	0.29	-1.15	-1.04
92.61	93.28	93.65	2.5	1.97	1.65	0.16	-1	-1.04

92.68	93.39	93.7	2.3	1.79	1.55	0.1	-0.94	-1.04

Blue at 5%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
92.11	93.57	93.21	2.07	1.35	1.36	-5.11	-3.71	-3.96
91.71	93.67	93.24	1.89	1.3	1.34	-5.17	-3.57	-4.02
91.74	92.94	93.53	1.9	1.54	1.34	-5.02	-4.02	-3.68
92.15	93.1	93.05	1.96	1.32	1.42	-4.77	-3.82	-4.15
91.55	93.14	93.13	2.06	1.43	1.35	-5.23	-3.93	-4.14
91.46	93.41	93.26	1.96	1.4	1.44	-5.34	-3.7	-4.02
91.41	92.51	93.22	2.17	1.66	1.5	-5.36	-4.39	-3.95
92.01	92.45	93.42	1.98	1.47	1.32	-4.85	-4.4	-3.91
91.82	93.03	93.14	2.02	1.49	1.41	-5.12	-4.07	-4.19
91.63	93.34	93.54	1.91	1.43	1.39	-5.22	-3.72	-4.06

Green at 5%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
94.09	94.77	94.46	-1.11	-0.05	-0.12	-0.92	-2.03	-1.9
93.64	94.44	94.37	-1.18	-0.24	-0.3	-0.71	-1.84	-2.02
93.62	94.37	94.12	-1.21	-0.32	-0.62	-0.83	-1.63	-1.7
93.2	94.11	94.17	-1.68	-0.3	-0.66	-0.69	-1.88	-1.58
93.02	94.22	94.31	-1.67	-0.43	-0.61	-0.53	-1.83	-1.68
93.6	94.41	94.36	-1.49	-0.19	-0.41	-0.44	-1.93	-1.89
93.36	94.43	94.36	-1.68	-0.53	-0.49	-0.46	-1.59	-1.74
93.52	94.7	94.43	-1.48	-0.22	-0.55	-0.97	-1.95	-1.53
93.38	94.41	94.51	-1.67	-0.39	-0.46	-0.58	-1.79	-1.67
93.56	94.47	94.33	-1.46	-0.33	-0.51	-0.45	-1.9	-1.84

3-color Black at 5%

L			a			b		
HA	HB	HC	HA	HB	HC	HA	HB	HC
93.15	94.21	94.19	0.88	0.98	0.86	-1.81	-2.42	-2.54
93.75	94.32	94.22	0.85	0.82	0.79	-1.95	-2.48	-2.29
93.69	94.32	94.2	0.9	0.83	0.8	-1.86	-2.48	-2.34
92.75	94.03	93.84	1.02	0.89	0.83	-1.78	-2.29	-2.42
92.65	93.98	93.88	1.02	0.88	0.86	-1.9	-2.44	-2.45
92.73	94.15	94.03	1	0.78	0.82	-1.71	-2.37	-2.25
92.8	94.25	94.12	1.04	0.87	0.88	-1.61	-2.45	-2.51
93.05	94.18	93.81	1.04	0.9	0.81	-1.81	-2.34	-2.4
92.79	94.11	93.91	0.97	0.86	0.81	-1.82	-2.42	-2.42
92.54	93.88	93.99	1.03	0.83	0.84	-1.74	-2.39	-2.24

Cyan at 97%

	L	a	b
Halftone A	60.69	-32.54	-44.4
Halftone A	60.21	-33.12	-44.69
Halftone A	59.84	-33.58	-45.1
Halftone A	59.51	-33.31	-45.33
Halftone A	59.88	-33.03	-44.81
Halftone A	59.77	-33.42	-45.1
Halftone A	59.83	-33.73	-45.08
Halftone A	59.14	-33.43	-45.78
Halftone A	59.27	-33.46	-45.58
Halftone A	60.09	-33.01	-44.76
Halftone B	59.02	-34.05	-46.37
Halftone B	58.98	-34.36	-46.28
Halftone B	58.44	-33.99	-46.56
Halftone B	58.39	-34.36	-46.76
Halftone B	59.17	-33.53	-45.74
Halftone B	59.15	-33.9	-45.87
Halftone B	58.57	-33.94	-46.39
Halftone B	58.89	-33.71	-46.11
Halftone B	59.04	-33.76	-45.96
Halftone B	59.05	-34.26	-46.19
Halftone C	60.53	-32.19	-44.32
Halftone C	59.95	-32.93	-45.01
Halftone C	59.88	-33.16	-45.14
Halftone C	60.03	-33.32	-45.02
Halftone C	59.42	-33.27	-45.47
Halftone C	59.98	-32.75	-44.86
Halftone C	60.32	-32.67	-44.55
Halftone C	60.11	-33.38	-45.04
Halftone C	59.55	-33.01	-45.44
Halftone C	60.36	-32.4	-44.57

Magenta at 97%

	L	a	b
Halftone A	52.16	66.38	-5.52
Halftone A	51.91	66.65	-5.78
Halftone A	52.31	65.48	-5.61
Halftone A	51.76	66.59	-5.65
Halftone A	52.05	65.9	-5.58
Halftone A	52.92	64.21	-5.8
Halftone A	52.32	65.41	-5.66
Halftone A	52.27	65.47	-5.73
Halftone A	52.43	65.15	-5.71
Halftone A	52.18	65.89	-5.77
Halftone B	51.33	68.43	-6.36
Halftone B	51.21	68.52	-6.36
Halftone B	51.24	68.12	-6.09
Halftone B	51.38	67.63	-6.24
Halftone B	51.67	67.11	-6.23
Halftone B	50.97	68.64	-6.25
Halftone B	51.25	68.29	-6.42
Halftone B	51.45	67.58	-6.31
Halftone B	51.37	68.01	-6.18
Halftone B	51.67	67.57	-6.51
Halftone C	51.06	68.26	-5.57
Halftone C	51.82	66.55	-5.65
Halftone C	51.37	67.34	-5.67
Halftone C	51.41	67.35	-5.56
Halftone C	51.31	67.76	-5.77
Halftone C	51.48	67.33	-5.8
Halftone C	51.79	66.3	-5.72
Halftone C	51.75	67	-5.59
Halftone C	51.53	67.18	-5.75
Halftone C	51.98	66.38	-5.69

Yellow at 97%

	L	a	b
Halftone A	90.5	-7.77	78.87
Halftone A	90.51	-7.71	79.84
Halftone A	90.57	-7.68	78.53
Halftone A	90.52	-7.66	78.44
Halftone A	90.43	-7.68	78.55
Halftone A	90.5	-7.69	78.9
Halftone A	90.45	-7.7	78.21

4-color Black at 97%

	L	a	b
Halftone A	23.72	1.61	-0.13
Halftone A	23.92	1.57	-0.43
Halftone A	23.01	1.79	-1.16
Halftone A	25.05	2.31	-1.72
Halftone A	25.04	1.67	-1.25
Halftone A	24.18	2.15	-1.46
Halftone A	22.96	1.79	-1.19

Halftone A	90.5	-7.64	78.44	Halftone A	23.14	2.01	-2.12
Halftone A	90.56	-7.66	78.03	Halftone A	24.24	1.53	-1.1
Halftone A	90.59	-7.76	78.54	Halftone A	37.19	9.98	1.44
Halftone B	90.45	-7.7	82.15	Halftone B	21.1	2.17	0.64
Halftone B	90.47	-7.65	81.5	Halftone B	20.14	2.53	0.35
Halftone B	90.45	-7.75	80.59	Halftone B	20.87	2.81	0
Halftone B	90.45	-7.71	81.16	Halftone B	20.84	1.89	0.62
Halftone B	90.43	-7.72	80.4	Halftone B	21.12	2.16	0.02
Halftone B	90.41	-7.66	80.58	Halftone B	21.48	2.17	0.53
Halftone B	90.37	-7.72	80.63	Halftone B	20.72	2.52	0.12
Halftone B	90.41	-7.68	80.28	Halftone B	21.11	1.75	0.76
Halftone B	90.47	-7.67	80.71	Halftone B	22.32	2.14	-0.06
Halftone B	90.43	-7.6	81.42	Halftone B	36.03	12.82	3.37
Halftone C	90.41	-7.92	77.11	Halftone C	24.23	0.25	1.98
Halftone C	90.56	-7.7	77.53	Halftone C	25.35	0.52	1.69
Halftone C	90.58	-7.76	76.57	Halftone C	25.37	0.57	1.33
Halftone C	90.55	-7.75	75.17	Halftone C	24.65	0.04	1.38
Halftone C	90.63	-7.71	74.82	Halftone C	26.41	0.48	1.69
Halftone C	90.7	-7.81	76.52	Halftone C	26.1	0.45	1.41
Halftone C	90.61	-7.74	76.63	Halftone C	25.95	0.21	1.21
Halftone C	90.56	-7.69	75.61	Halftone C	26.67	0.21	1.51
Halftone C	90.59	-7.72	76.18	Halftone C	37.06	9.97	4.25
Halftone C	90.62	-7.73	76.17	Halftone C	37.3	9.97	4.16

Cyan at 50% **Magenta at 50%**

	L	a	b		L	a	b
Halftone A	81.95	-10.4	-18.11	Halftone A	77.78	24.02	-6.53
Halftone A	82.18	-10.26	-17.85	Halftone A	78.51	22.73	-6.43
Halftone A	82.4	-10.54	-17.86	Halftone A	78.08	23.11	-6.29
Halftone A	81.96	-10.69	-18.19	Halftone A	78.26	22.71	-6.29
Halftone A	82.63	-10.27	-17.4	Halftone A	78.08	22.83	-6.31
Halftone A	82.25	-10.41	-17.83	Halftone A	78.26	22.63	-6.3
Halftone A	82.28	-10.17	-17.66	Halftone A	78.63	22.21	-6.2
Halftone A	81.76	-10.88	-18.49	Halftone A	78.86	21.95	-6.43
Halftone A	82.47	-10.58	-17.75	Halftone A	78.78	22.04	-6.31
Halftone A	82.73	-10.1	-17.26	Halftone A	79.2	21.59	-6.18
Halftone B	83.05	-10.8	-17.49	Halftone B	77.53	24.42	-6.32
Halftone B	81.89	-11.56	-18.61	Halftone B	77.81	23.92	-7.08
Halftone B	82.18	-11.41	-18.38	Halftone B	77.13	25.17	-7.16
Halftone B	82.09	-11.21	-18.36	Halftone B	77.21	24.86	-7.01
Halftone B	81.92	-11.07	-18.47	Halftone B	77.68	24.26	-7
Halftone B	82.56	-10.76	-17.9	Halftone B	78.4	23.13	-6.74
Halftone B	82.99	-10.79	-17.51	Halftone B	78.07	23.44	-6.84
Halftone B	82.25	-11.22	-18.28	Halftone B	78.35	23.43	-6.98
Halftone B	81.7	-11.42	-18.79	Halftone B	77.85	24.1	-6.95

Halftone B	82.79	-11.28	-17.82	Halftone B	78.68	22.87	-6.75
Halftone C	82.17	-11.31	-18.39	Halftone C	77.57	24.3	-6.99
Halftone C	81.78	-11.29	-18.69	Halftone C	78.37	22.95	-6.3
Halftone C	81.81	-10.77	-18.34	Halftone C	77.28	24.38	-6.52
Halftone C	82.51	-10.72	-17.84	Halftone C	77.37	24.23	-6.57
Halftone C	82.58	-10.82	-17.78	Halftone C	77.51	24	-6.38
Halftone C	82.1	-10.76	-18.2	Halftone C	78.2	23.04	-6.34
Halftone C	81.71	-11.15	-18.7	Halftone C	78.77	22.25	-6.21
Halftone C	82.3	-10.88	-18.1	Halftone C	78.47	22.78	-6.36
Halftone C	82.01	-11.19	-18.34	Halftone C	78.2	23	-6.2
Halftone C	82.11	-10.79	-18.34	Halftone C	78.21	23.22	-6.32

Yellow at 50% / **4-color Black at 50%**

Yellow at 50%	L	a	b	4-color Black at 50%	L	a	b
Halftone A	93.46	-3.47	22.41	Halftone A	72.42	-0.69	-2.9
Halftone A	93.18	-3.12	18.31	Halftone A	72.59	-0.43	-2.85
Halftone A	93.29	-3.43	21.44	Halftone A	72.05	-0.51	-2.8
Halftone A	93.35	-3.27	20.49	Halftone A	72.45	-0.74	-2.94
Halftone A	93.18	-3.38	21.54	Halftone A	72.73	-0.62	-2.92
Halftone A	93.3	-3.34	21.64	Halftone A	73.24	-0.55	-3.19
Halftone A	93.43	-3.25	20.54	Halftone A	72.51	-0.57	-3.32
Halftone A	93.43	-3.27	21.09	Halftone A	72.46	-0.75	-3.38
Halftone A	93.41	-3.16	19.82	Halftone A	73	-0.69	-3.01
Halftone A	93.39	-3.2	19.66	Halftone A	73.05	-0.75	-2.94
Halftone B	93.46	-3.65	22.82	Halftone B	71.95	-0.46	-3.09
Halftone B	93.34	-3.47	21.09	Halftone B	71.72	-0.83	-3.32
Halftone B	93.23	-3.57	21.65	Halftone B	71.49	-0.28	-2.79
Halftone B	93.16	-3.52	21.5	Halftone B	71.2	0.18	-2.45
Halftone B	93.09	-3.6	22.07	Halftone B	71.96	-0.05	-2.19
Halftone B	93.16	-3.42	20.61	Halftone B	71.53	-0.37	-3.31
Halftone B	93.1	-3.6	22.24	Halftone B	72.45	-0.61	-3.27
Halftone B	93.22	-3.54	21.77	Halftone B	72.74	0.15	-3.02
Halftone B	93.28	-3.4	20.47	Halftone B	72.01	-0.39	-3.44
Halftone B	93.43	-3.32	20.07	Halftone B	72.54	-0.3	-3.71
Halftone C	93.47	-3.07	19	Halftone C	73.43	0.54	-2.66
Halftone C	93.31	-3.24	20.35	Halftone C	73.39	-0.04	-2.88
Halftone C	93.43	-3.18	19.52	Halftone C	74.22	-0.01	-2.39
Halftone C	93.32	-3.25	20.56	Halftone C	73.42	-0.26	-2.62
Halftone C	93.41	-3.12	19.8	Halftone C	73.97	-0.2	-2.65
Halftone C	93.45	-2.97	18.31	Halftone C	74.91	-0.29	-2.45
Halftone C	93.43	-3.16	19.77	Halftone C	75.13	0.04	-2.12
Halftone C	93.56	-3.09	19.03	Halftone C	74.2	-0.13	-2.67
Halftone C	93.58	-3.03	18.95	Halftone C	74.12	-0.22	-3.06
Halftone C	93.5	-3.19	20.07	Halftone C	75.29	-0.23	-2.45

Cyan at 10%

	L	a	b
Halftone A	93.25	-1.32	-5.12
Halftone A	93.34	-1.31	-4.94
Halftone A	93.15	-1.41	-5.2
Halftone A	92.98	-1.51	-5.39
Halftone A	93.09	-1.57	-5.34
Halftone A	93.26	-1.32	-4.98
Halftone A	93.01	-1.5	-5.37
Halftone A	92.92	-1.53	-5.44
Halftone A	92.96	-1.47	-5.43
Halftone A	93.1	-1.41	-5.15
Halftone B	93.42	-1.16	-4.9
Halftone B	93.45	-0.99	-4.8
Halftone B	93.55	-0.94	-4.68
Halftone B	93.44	-0.83	-4.6
Halftone B	93.23	-1.04	-4.79
Halftone B	93.36	-0.9	-4.74
Halftone B	93.66	-0.86	-4.47
Halftone B	93.49	-1	-4.69
Halftone B	93.2	-1.24	-5.06
Halftone B	93.4	-0.96	-4.82
Halftone C	93.4	-1.11	-4.66
Halftone C	93.18	-1.21	-5.06
Halftone C	93.02	-1.42	-5.3
Halftone C	93.16	-1.39	-5.21
Halftone C	93.27	-1.4	-5
Halftone C	93.17	-1.44	-5.2
Halftone C	93.08	-1.42	-5.17
Halftone C	93.08	-1.41	-5.26
Halftone C	93.36	-1.24	-4.9
Halftone C	93.34	-1.21	-4.94

Magenta at 10%

	L	a	b
Halftone A	92.29	4.58	-3.66
Halftone A	92.2	4.51	-3.69
Halftone A	91.99	4.6	-3.81
Halftone A	92.1	4.42	-3.78
Halftone A	91.99	4.49	-3.8
Halftone A	91.98	4.5	-3.85
Halftone A	91.96	4.63	-3.82
Halftone A	92.19	4.28	-3.74
Halftone A	92.18	4.42	-3.71
Halftone A	93.06	3.48	-3.33
Halftone B	93.03	3.69	-3.41
Halftone B	92.86	3.68	-3.56
Halftone B	92.88	3.73	-3.6
Halftone B	92.84	3.75	-3.56
Halftone B	93.12	3.47	-3.5
Halftone B	92.64	4.1	-3.61
Halftone B	92.99	3.54	-3.55
Halftone B	93.06	3.4	-3.39
Halftone B	92.99	3.65	-3.5
Halftone B	92.68	4.05	-3.73
Halftone C	92.62	4.01	-3.49
Halftone C	92.57	4.1	-3.81
Halftone C	92.68	3.98	-3.66
Halftone C	92.59	4.02	-3.71
Halftone C	92.5	4.15	-3.7
Halftone C	92.37	4.35	-3.82
Halftone C	92.45	4.17	-3.72
Halftone C	92.79	3.8	-3.66
Halftone C	92.62	3.95	-3.61
Halftone C	92.34	4.2	-3.63

Yellow at 10%

	L	a	b
Halftone A	95.06	0.63	-2.07
Halftone A	95.07	0.55	-1.91
Halftone A	95.07	0.45	-1.72
Halftone A	95.14	0.53	-2.32
Halftone A	95.12	0.45	-1.69
Halftone A	95.12	0.41	-1.69
Halftone A	95.01	0.4	-1.31
Halftone A	95.03	0.15	-0.57

4-color Black at 10%

	L	a	b
Halftone A	90.94	1.06	-1.49
Halftone A	91.04	0.98	-1.37
Halftone A	90.59	0.98	-1.52
Halftone A	90.67	0.82	-1.77
Halftone A	90.65	1	-1.51
Halftone A	90.74	1.15	-1.28
Halftone A	91.02	0.91	-1.52
Halftone A	90.41	0.82	-1.56

Halftone A	95	0.02	0.07	Halftone A	90.94	1.01	-1.51
Halftone A	95.11	0.34	-1.12	Halftone A	90.93	1.01	-1.28
Halftone B	95.25	0.77	-2.68	Halftone B	92.08	0.59	-2.1
Halftone B	95.1	0.71	-2.65	Halftone B	91.54	0.71	-2.29
Halftone B	95.07	0.7	-2.64	Halftone B	91.5	0.52	-2.52
Halftone B	94.99	0.66	-2.63	Halftone B	91.69	0.6	-2.18
Halftone B	95.03	0.72	-2.77	Halftone B	91.55	0.69	-2.06
Halftone B	95.03	0.68	-2.72	Halftone B	91.67	0.57	-2.35
Halftone B	95.07	0.74	-2.8	Halftone B	91.02	0.66	-2.44
Halftone B	95.07	0.72	-2.76	Halftone B	91.32	0.76	-2.2
Halftone B	95.13	0.69	-2.61	Halftone B	91.25	0.79	-1.99
Halftone B	95.02	0.71	-2.68	Halftone B	91.38	0.66	-2.01
Halftone C	95.18	0.67	-2.49	Halftone C	92.2	0.59	-2.2
Halftone C	95.16	0.57	-2.43	Halftone C	91.88	0.77	-2.04
Halftone C	95.23	0.54	-2.28	Halftone C	92.28	0.7	-2.11
Halftone C	95.16	0.59	-2.38	Halftone C	91.79	0.73	-2.14
Halftone C	95.28	0.59	-2.52	Halftone C	91.73	0.58	-2.26
Halftone C	95.13	0.56	-2.23	Halftone C	92.42	0.56	-2.27
Halftone C	95.24	0.6	-2.48	Halftone C	92.1	0.69	-2.02
Halftone C	95.27	0.51	-2.17	Halftone C	92.15	0.53	-2.19
Halftone C	95.18	0.6	-2.5	Halftone C	91.65	0.5	-2.32
Halftone C	95.29	0.61	-2.57	Halftone C	91.95	0.61	-2.17

Cyan at 5% **Magenta at 5%**

	L	a	b		L	a	b
Halftone A	94.41	-0.48	-4.02	Halftone A	93.81	2.29	-3.16
Halftone A	94.04	-0.59	-4.09	Halftone A	92.91	3.44	-3.5
Halftone A	93.97	-0.75	-4.34	Halftone A	93.14	3.06	-3.43
Halftone A	93.55	-0.9	-4.59	Halftone A	93.14	3.03	-3.48
Halftone A	93.14	-0.96	-4.77	Halftone A	93.2	3.09	-3.58
Halftone A	93.59	-0.84	-4.55	Halftone A	93.12	2.92	-3.31
Halftone A	93.97	-0.64	-4.26	Halftone A	93.28	2.71	-3.37
Halftone A	93.63	-0.95	-4.61	Halftone A	93.2	2.85	-3.41
Halftone A	93.54	-1.02	-4.8	Halftone A	93.13	3.12	-3.56
Halftone A	93.56	-0.89	-4.72	Halftone A	92.97	3.24	-3.52
Halftone B	94.53	0.11	-3.49	Halftone B	94.73	1.54	-2.84
Halftone B	94.08	-0.05	-3.56	Halftone B	94.5	1.6	-2.97
Halftone B	94.14	-0.03	-3.74	Halftone B	94.47	1.63	-2.87
Halftone B	93.75	-0.24	-3.88	Halftone B	94.38	1.75	-2.99
Halftone B	93.5	-0.35	-4.17	Halftone B	94.17	1.96	-3.07
Halftone B	94.03	-0.05	-3.75	Halftone B	94.25	1.82	-3.03
Halftone B	93.77	-0.3	-3.9	Halftone B	94.25	1.76	-2.92
Halftone B	93.95	-0.38	-3.94	Halftone B	94.1	1.81	-3.05
Halftone B	93.75	-0.34	-4.01	Halftone B	94.28	1.94	-3.11
Halftone B	94.03	-0.2	-3.81	Halftone B	94.09	1.96	-3.13

Halftone C	94.91	0.09	-3.28	Halftone C	94.58	1.71	-2.99
Halftone C	94.17	-0.32	-3.97	Halftone C	94.28	2.05	-3.14
Halftone C	94.06	-0.45	-4.01	Halftone C	94.37	1.71	-3.06
Halftone C	94.32	-0.21	-3.7	Halftone C	94.04	2.11	-3.15
Halftone C	94.27	-0.22	-3.75	Halftone C	94.23	1.97	-3.07
Halftone C	94.06	-0.42	-4.01	Halftone C	94.25	1.9	-3.1
Halftone C	94.29	-0.38	-3.89	Halftone C	94.37	1.57	-3.04
Halftone C	94.13	-0.36	-3.96	Halftone C	94.44	1.63	-3.03
Halftone C	94.38	-0.15	-3.79	Halftone C	94.24	1.97	-3.19
Halftone C	94.13	-0.34	-3.92	Halftone C	93.98	2.04	-3.17

4-color Black at 5%

4 color Black at around 5%

	L	a	b
Halftone A	93.08	0.68	-2.05
Halftone A	92.45	0.71	-1.79
Halftone A	93.18	0.73	-1.82
Halftone A	92.88	0.72	-1.7
Halftone A	92.09	0.71	-1.89
Halftone A	92.64	0.73	-1.81
Halftone A	92.9	0.83	-1.8
Halftone A	92.36	0.79	-1.73
Halftone A	92.12	0.76	-1.88
Halftone A	92.83	0.7	-1.89
Halftone B	93.96	0.7	-2.39
Halftone B	94.02	0.52	-2.45
Halftone B	93.98	0.57	-2.43
Halftone B	93.96	0.58	-2.31
Halftone B	93.76	0.59	-2.41
Halftone B	94.16	0.54	-2.55
Halftone B	93.93	0.66	-2.48
Halftone B	93.95	0.62	-2.33
Halftone B	93.68	0.6	-2.28
Halftone B	93.81	0.59	-2.51
Halftone C	94.13	0.59	-2.38
Halftone C	93.98	0.58	-2.25
Halftone C	93.85	0.55	-2.25
Halftone C	93.52	0.43	-2.23
Halftone C	93.44	0.54	-2.29
Halftone C	93.92	0.58	-2.17
Halftone C	93.52	0.58	-2.27
Halftone C	93.43	0.47	-2.34
Halftone C	93.63	0.52	-2.32
Halftone C	93.69	0.61	-2.17

Appendix I

ANOVA Tables and Descriptive Statistics Used to Establish the Baseline

Paper Used for the Printed Samples

ANOVA: Paper at 0%

SUMMARY

Groups	Count	Sum	Average	Variance
L	30	2839.69	94.65633	0.081265
a	30	34.08	1.136	0.031418
b	30	-94.97	-3.16567	0.007791

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	183337	2	91668.5	2282691	4.8E-206	3.101292
Within Groups	3.493753	87	0.040158			
Total	183340.5	89				

Descriptive Statistics for the Paper

Descriptive Statistics for Paper Variance					
L		a		b	
Mean	94.65633	Mean	1.136	Mean	-3.16567
Standard Error	0.052047	Standard Error	0.032361	Standard Error	0.016115
Median	94.715	Median	1.19	Median	-3.165
Mode	94.66	Mode	1.24	Mode	-3.12
Standard Deviation	0.285071	Standard Deviation	0.177251	Standard Deviation	0.088266
Sample Variance	0.081265	Sample Variance	0.031418	Sample Variance	0.007791
Kurtosis	1.533281	Kurtosis	-0.16147	Kurtosis	2.216347
Skewness	-1.32056	Skewness	-0.68058	Skewness	1.158293
Range	1.13	Range	0.73	Range	0.41
Minimum	93.87	Minimum	0.76	Minimum	-3.31
Maximum	95	Maximum	1.49	Maximum	-2.9
Sum	2839.69	Sum	34.08	Sum	-94.97
Count	30	Count	30	Count	30
Confidence Level(95.0%)	0.106447	Confidence Level(95.0%)	0.066187	Confidence Level(95.0%)	0.032959

Descriptive Stats for 2 reads in the same place	
Mean	0.157667
Standard Error	0.007974
Median	0.16
Mode	0.14
Standard Deviation	0.061764
Sample Variance	0.003815
Kurtosis	2.328287
Skewness	0.743133
Range	0.37
Minimum	0.02
Maximum	0.39
Sum	9.46
Count	60
Confidence Level(95.0%)	0.015955

ANOVAs for Process color or Transparent Inks used in the Study

ANOVA: Halftone A Cyan at around 97%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	598.23	59.823	0.20549
a	10	-332.63	-33.263	0.11929
b	10	-450.63	-45.063	0.17669

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	66017.72	2	33008.86	197472.6	5.89E-57	3.354131
Within Groups	4.51323	27	0.167157			
Total	66022.23	29				

ANOVA: Halftone B Cyan at around 97%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	588.7	58.87	0.085556
a	10	-339.86	-33.986	0.078182
b	10	-462.23	-46.223	0.099512

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	66055.07	2	33027.53	376382.1	9.73E-61	3.354131
Within Groups	2.36925	27	0.08775			
Total	66057.43	29				

ANOVA: Halftone C Cyan at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	600.13	60.013	0.120046
a	10	-329.08	-32.908	0.161462
b	10	-449.42	-44.942	0.141329

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	65982.27	2	32991.14	234070.1	5.93E-58	3.354131
Within Groups	3.80553	27	0.140946			
Total	65986.08	29				

ANOVA: Halftone A Magenta at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	522.31	52.231	0.099477
a	10	657.13	65.713	0.548823
b	10	-56.81	-5.681	0.008632

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	28775.56	2	14387.78	65704.4	1.66E-50	3.354131
Within Groups	5.91239	27	0.218977			
Total	28781.47	29				

ANOVA: Halftone B Magenta at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	513.54	51.354	0.044716
a	10	679.9	67.99	0.250311
b	10	-62.95	-6.295	0.015006

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	30394.75	2	15197.37	147056.1	3.15E-55	3.354131
Within Groups	2.79029	27	0.103344			
Total	30397.54	29				

ANOVA: Halftone C Magenta at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	515.5	51.55	0.078933
a	10	671.45	67.145	0.379028
b	10	-56.77	-5.677	0.007179

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	29403.92	2	14701.96	94822.82	1.18E-52	3.354131
Within Groups	4.18626	27	0.155047			
Total	29408.11	29				

ANOVA: Halftone A Yellow at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	905.13	90.513	0.002534
a	10	-76.95	-7.695	0.001783
b	10	786.35	78.635	0.247494

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	57462.56	2	28731.28	342294.1	3.51E-60	3.354131
Within Groups	2.26631	27	0.083937			
Total	57464.82	29				

ANOVA: Halftone B Yellow at around 97%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	904.34	90.434	0.00096
a	10	-76.86	-7.686	0.001871
b	10	809.42	80.942	0.353862

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	58575.18	2	29287.59	246325.8	2.98E-58	3.354131
Within Groups	3.21024	27	0.118898			
Total	58578.39	29				

ANOVA: Halftone C Yellow at around 97%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	905.81	90.581	0.005566
a	10	-77.53	-7.753	0.004623
b	10	762.31	76.231	0.702921

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	56429.37	2	28214.68	118697	5.67E-54	3.354131
Within Groups	6.41799	27	0.237703			
Total	56435.79	29				

Density, Dot Gain, and Print Contrast

Density values of 4-color Black at 50%

Groups	*Count*	*Sum*	*Average*	*Variance*
HA	40	16.11	0.40275	2.04E-05
HB	40	17.29	0.43225	3.33E-05
HC	40	16.1	0.4025	1.92E-05

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.023405	2	0.011703	481.2627	3.51E-57	3.073765
Within Groups	0.002845	117	2.43E-05			
Total	0.02625	119			**Reject Null**	

Actual Dot %

Groups	*Count*	*Sum*	*Average*	*Variance*
HA	40	2460	61.5	0.25641
HB	40	2568	64.2	0.215385
HC	40	2460	61.5	0.25641

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	194.4	2	97.2	400.4366	4.64E-53	3.073765
Within Groups	28.4	117	0.242735			
Total	222.8	119			**Reject Null**	

Dot Gain

Groups	*Count*	*Sum*	*Average*	*Variance*
HA	40	460	11.5	0.25641
HB	40	568	14.2	0.215385
HC	40	463	11.575	0.250641

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	189.15	2	94.575	392.7338	1.25E-52	3.073765
Within Groups	28.175	117	0.240812			
Total	217.325	119			**Reject Null**	

Print Contrast

Print Contrast		3-color Black at 75%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	252	25.2	0.622222
HB	10	203	20.3	0.9
HC	10	222	22.2	0.844444

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	122.0667	2	61.03333	77.3662	6.62E-12	3.354131
Within Groups	21.3	27	0.788889			
Total	143.3667	29			**Reject Null**	

Print Contrast		4-color Black at 75%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	533	53.3	0.677778
HB	10	507	50.7	1.344444
HC	10	538	53.8	0.177778

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	55.4	2	27.7	37.77273	1.5E-08	3.354131
Within Groups	19.8	27	0.733333			
Total	75.2	29			**Reject Null**	

Print Contrast		Magenta at 75%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	375	37.5	0.944444
HB	10	383	38.3	0.9
HC	10	392	39.2	1.288889

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14.46667	2	7.233333	6.925532	0.003734	3.354131
Within Groups	28.2	27	1.044444			
Total	42.66667	29			**Reject Null**	

Print Contrast		Red at 75%		
Groups	*Count*	*Sum*	*Average*	*Variance*

HA	10	362	36.2	11.51111
HB	10	344	34.4	7.822222
HC	10	285	28.5	11.16667

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	324.4667	2	162.2333	15.95738	2.66E-05	3.354131
Within Groups	274.5	27	10.16667			
Total	598.9667	29			**Reject Null**	

Print Contrast Cyan at 75%

Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	384	38.4	6.711111
HB	10	318	31.8	12.4
HC	10	364	36.4	5.6

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	229.0667	2	114.5333	13.90468	7.06E-05	3.354131
Within Groups	222.4	27	8.237037			
Total	451.4667	29			**Reject Null**	

Print Contrast Yellow at 75%

Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	345	34.5	0.277778
HB	10	278	27.8	1.288889
HC	10	341	34.1	0.322222

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	282.4667	2	141.2333	224.3118	1.51E-17	3.354131
Within Groups	17	27	0.62963			
Total	299.4667	29			**Reject Null**	

Appendix J

ANOVA Tables for the Analysis of Two, Three, and Four Color Overprints

2-color Overprints

ANOVA: Halftone A Red at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	20	974.55	48.7275	0.015136
a	20	1339.02	66.951	0.480125
b	20	842.71	42.1355	0.139142

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6609.063	2	3304.532	15626.66	8.23E-79	3.158846
Within Groups	12.05365	57	0.211468			
Total	6621.117	59				

ANOVA: Halftone B Red at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	20	961.73	48.0865	0.028571
a	20	1358.63	67.9315	0.12155
b	20	892.3	44.615	0.096142

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6330.23	2	3165.115	38557.63	5.62E-90	3.158846
Within Groups	4.67901	57	0.082088			
Total	6334.909	59				

ANOVA: Halftone C Red at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance

L	20	960.63	48.0315	0.034319
a	20	1364.68	68.234	0.351699
b	20	861	43.05	0.100811

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7114.601	2	3557.301	21921.29	5.4E-83	3.158846
Within Groups	9.249735	57	0.162276			
Total	7123.851	59				

ANOVA for Red at 97%

L values		Red at 97%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	20	974.55	48.7275	0.015136
HB	20	961.73	48.0865	0.028571
HC	20	960.63	48.0315	0.034319

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.988813	2	2.994407	115.1318	9.58E-21	3.158846
Within Groups	1.482485	57	0.026009			
Total	7.471298	59			**Reject Null**	

a values		Red at 97%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	20	1339.02	66.951	0.480125
HB	20	1358.63	67.9315	0.12155
HC	20	1364.68	68.234	0.351699

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	17.99317	2	8.996585	28.30971	2.9E-09	3.158846
Within Groups	18.11411	57	0.317791			
Total	36.10728	59			**Reject Null**	

b values		Red at 97%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	20	842.71	42.1355	0.139142
HB	20	892.3	44.615	0.096142
HC	20	861	43.05	0.100811

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	62.8897	2	31.44485	280.6787	3.11E-30	3.158846
Within Groups	6.385795	57	0.112031			
Total	69.2755	59			**Reject Null**	

ANOVA: Halftone A Red at around 50%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	772.07	77.207	0.106668
a	10	189.17	18.917	0.145979
b	10	184.47	18.447	0.069201

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22835.61	2	11417.8	106427.4	2.47E-53	3.354131
Within Groups	2.89663	27	0.107283			
Total	22838.51	29				

ANOVA: Halftone B Red at around 50%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	754.17	75.417	0.488912
a	10	216.88	21.688	1.312796
b	10	193.58	19.358	0.087218

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20116.15	2	10058.08	15974.28	3.22E-42	3.354131

Within Groups	17.00033	27	0.629642
Total	20133.15	29	

ANOVA: Halftone C Red at around 50%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	760.72	76.072	0.06064
a	10	205.52	20.552	0.099862
b	10	189.11	18.911	0.148766

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	21175.14	2	10587.57	102703	4E-53	3.354131
Within Groups	2.78341	27	0.103089			
Total	21177.93	29				

ANOVA for Red at 50%

L values — Red at 50%

Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	772.07	77.207	0.106668
HB	10	754.17	75.417	0.488912
HC	10	760.72	76.072	0.06064

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.4045	2	8.20225	37.49771	1.61E-08	3.354131
Within Groups	5.90598	27	0.21874			
Total	22.31048	29			**Reject Null**	

a values — Red at 50%

Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	189.17	18.917	0.145979
HB	10	216.88	21.688	1.312796
HC	10	205.52	20.552	0.099862

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	38.80721	2	19.4036	37.34726	1.68E-08	3.354131
Within Groups	14.02773	27	0.519546			
Total	52.83494	29			**Reject Null**	

b values		Red at 50%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	184.47	18.447	0.069201
HB	10	193.58	19.358	0.087218
HC	10	189.11	18.911	0.148766

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.150087	2	2.075043	20.39793	4E-06	3.354131
Within Groups	2.74666	27	0.101728			
Total	6.896747	29			**Reject Null**	

ANOVA for Red at 10%

L values		Red at 10%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	919.31	91.931	0.005254
HB	10	926.54	92.654	0.027582
HC	10	923.37	92.337	0.011646

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.626847	2	1.313423	88.58078	1.38E-12	3.354131
Within Groups	0.40034	27	0.014827			
Total	3.027187	29			**Reject Null**	

a values		Red at 10%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	33.49	3.349	0.004099
HB	10	27.04	2.704	0.013782
HC	10	30.34	3.034	0.018249

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.0805	2	1.04025	86.37559	1.85E-12	3.354131
Within Groups	0.32517	27	0.012043			
Total	2.40567	29			**Reject Null**	

a values		Red at 10%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	12.44	1.244	0.013227
HB	10	1.17	0.117	0.018401
HC	10	6.75	0.675	0.014828

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6.350847	2	3.175423	205.062	4.73E-17	3.354131
Within Groups	0.4181	27	0.015485			
Total	6.768947	29			**Reject Null**	

ANOVA for Red at 5%

L values		Red at 5%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	934.99	93.499	0.083388
HB	10	944.33	94.433	0.03789
HC	10	943.42	94.342	0.014596

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.304287	2	2.652143	58.5577	1.52E-10	3.354131
Within Groups	1.22286	27	0.045291			
Total	6.527147	29			**Reject Null**	

a values		Red at 5%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	24.02	2.402	0.01404
HB	10	16.22	1.622	0.039218
HC	10	16.21	1.621	0.015832

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*

Between Groups	4.061207	2	2.030603	88.17209	1.45E-12	3.354131
Within Groups	0.62181	27	0.02303			
Total	4.683017	29			**Reject Null**	

b values Red at 5%

Groups	Count	Sum	Average	Variance
HA	10	1.75	0.175	0.010628
HB	10	-12.19	-1.219	0.043521
HC	10	-10.87	-1.087	0.012557

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	11.84435	2	5.922173	266.3424	1.68E-18	3.354131
Within Groups	0.60035	27	0.022235			
Total	12.4447	29			**Reject Null**	

ANOVA: Halftone A Blue at around 97%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	257.81	25.781	0.123166
a	10	344.26	34.426	0.572516
b	10	-389.95	-38.995	0.325361

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32204.36	2	16102.18	47311.02	1.4E-48	3.354131
Within Groups	9.18938	27	0.340347			
Total	32213.55	29				

ANOVA: Halftone B Blue at around 97%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	250.75	25.075	0.055628
a	10	332.14	33.214	0.443471
b	10	-398.11	-39.811	0.143077

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	32030.29	2	16015.14	74816.67	2.88E-51	3.354131
Within Groups	5.77958	27	0.214059			
Total	32036.07	29				

ANOVA: Halftone C Blue at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	257.87	25.787	0.069379
a	10	334.41	33.441	1.004654
b	10	-395.35	-39.535	0.167139

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	32170.15	2	16085.07	38878.75	1.98E-47	3.354131
Within Groups	11.17055	27	0.413724			
Total	32181.32	29				

ANOVA for Blue at 97%

L values		Blue at 97%		
Groups	Count	Sum	Average	Variance
HA	10	257.81	25.781	0.123166
HB	10	250.75	25.075	0.055628
HC	10	257.87	25.787	0.069379

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3.351387	2	1.675693	20.25642	4.23E-06	3.354131
Within Groups	2.23355	27	0.082724			
Total	5.584937	29			**Reject Null**	

a values		Blue at 97%		
Groups	Count	Sum	Average	Variance

HA	10	344.26	34.426	0.572516
HB	10	332.14	33.214	0.443471
HC	10	334.41	33.441	1.004654

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.302327	2	4.151163	6.163138	0.00624	3.354131
Within Groups	18.18577	27	0.673547			
Total	26.4881	29			**Reject Null**	

b values Blue at 97%

Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	-389.95	-38.995	0.325361
HB	10	-398.11	-39.811	0.143077
HC	10	-395.35	-39.535	0.167139

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.44544	2	1.72272	8.13145	0.001721	3.354131
Within Groups	5.72019	27	0.211859			
Total	9.16563	29			**Reject Null**	

ANOVA: Halftone A Blue at around 50%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	664.26	66.426	0.178538
a	10	107.44	10.744	0.178871
b	10	-201.45	-20.145	0.114361

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	38497.18	2	19248.59	122402.4	3.75E-54	3.354131
Within Groups	4.24593	27	0.157257			
Total	38501.42	29				

ANOVA: Halftone B Blue at around 50%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	661.7	66.17	0.278467
a	10	122.02	12.202	0.670218
b	10	-205.42	-20.542	0.105951

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	38345.62	2	19172.81	54538.68	2.05E-49	3.354131
Within Groups	9.49172	27	0.351545			
Total	38355.11	29				

ANOVA: Halftone C Blue at around 50%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	674.32	67.432	0.24284
a	10	99.86	9.986	0.18576
b	10	-197.97	-19.797	0.112401

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	39319.89	2	19659.95	109019.8	1.79E-53	3.354131
Within Groups	4.86901	27	0.180334			
Total	39324.76	29				

ANOVA for Blue at 50%

L values		Blue at 50%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	664.26	66.426	0.178538
HB	10	661.7	66.17	0.278467
HC	10	674.32	67.432	0.24284

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.90072	2	4.45036	19.07721	6.84E-06	3.354131

Within Groups	6.2986	27	0.233281			
Total	15.19932	29			**Reject Null**	

a values — Blue at 50%

Groups	Count	Sum	Average	Variance
HA	10	107.44	10.744	0.178871
HB	10	122.02	12.202	0.670218
HC	10	99.86	9.986	0.18576

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	25.36995	2	12.68497	36.77341	1.96E-08	3.354131
Within Groups	9.31364	27	0.34495			
Total	34.68359	29			**Reject Null**	

b values — Blue at 50%

Groups	Count	Sum	Average	Variance
HA	10	-201.45	-20.145	0.114361
HB	10	-205.42	-20.542	0.105951
HC	10	-197.97	-19.797	0.112401

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.779127	2	1.389563	12.52937	0.000141	3.354131
Within Groups	2.99442	27	0.110904			
Total	5.773547	29			**Reject Null**	

ANOVA for Blue at 10%

L values — Blue at 10%

Groups	Count	Sum	Average	Variance
HA	10	893.66	89.366	0.060071
HB	10	911.46	91.146	0.057027
HC	10	913.15	91.315	0.080472

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	23.31854	2	11.65927	177.0401	3.02E-16	3.354131

Within Groups	1.77813	27	0.065857			
Total	25.09667	29			**Reject Null**	

a values		Blue at 10%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	24.81	2.481	0.017677
HB	10	21.15	2.115	0.01725
HC	10	20.31	2.031	0.015966

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.14504	2	0.57252	33.74897	4.52E-08	3.354131
Within Groups	0.45803	27	0.016964			
Total	1.60307	29			**Reject Null**	

b values		Blue at 10%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	-68.4	-6.84	0.052667
HB	10	-55.72	-5.572	0.047551
HC	10	-55.09	-5.509	0.053543

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	11.27785	2	5.638923	110.0198	1.05E-13	3.354131
Within Groups	1.38385	27	0.051254			
Total	12.6617	29			**Reject Null**	

ANOVA for Blue at 5%

L values		Blue at 5%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	917.59	91.759	0.068566
HB	10	931.16	93.116	0.166627
HC	10	932.74	93.274	0.028316

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13.87213	2	6.936063	78.96613	5.23E-12	3.354131
Within Groups	2.37157	27	0.087836			

Total	16.2437	29			**Reject Null**	

a values Blue at 5%

Groups	Count	Sum	Average	Variance
HA	10	19.92	1.992	0.007884
HB	10	14.39	1.439	0.011743
HC	10	13.87	1.387	0.003134

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.24846	2	1.12423	148.1705	2.77E-15	3.354131
Within Groups	0.20486	27	0.007587			
Total	2.45332	29			**Reject Null**	

b values Blue at 5%

Groups	Count	Sum	Average	Variance
HA	10	-51.19	-5.119	0.037343
HB	10	-39.33	-3.933	0.083023
HC	10	-40.08	-4.008	0.02184

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.821807	2	4.410903	93.05267	7.72E-13	3.354131
Within Groups	1.27986	27	0.047402			
Total	10.10167	29			**Reject Null**	

ANOVA: Halftone A Green at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	569.68	56.968	0.305373
a	10	-560.64	-56.064	0.692204
b	10	212.81	21.281	1.994432

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	66773.48	2	33386.74	33475.9	1.49E-46	3.354131
Within Groups	26.92809	27	0.997337			

Total	66800.41	29				

ANOVA: Halftone B Green at around 97%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	586.56	58.656	0.552604
a	10	-542.74	-54.274	1.097516
b	10	229.38	22.938	2.073173

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	66635.51	2	33317.76	26845.39	2.93E-45	3.354131
Within Groups	33.50964	27	1.241098			
Total	66669.02	29				

ANOVA: Halftone C Green at around 97%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	588.27	58.827	0.136623
a	10	-534.39	-53.439	0.092988
b	10	239.85	23.985	1.079872

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	66040.32	2	33020.16	75648.52	2.48E-51	3.354131
Within Groups	11.78535	27	0.436494			
Total	66052.1	29				

ANOVA for Green at 97%

L values		Green at 97%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	569.68	56.968	0.305373
HB	10	586.56	58.656	0.552604
HC	10	588.27	58.827	0.136623

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	21.11489	2	10.55744	31.84425	7.88E-08	3.354131
Within Groups	8.95141	27	0.331534			
Total	30.0663	29			**Reject Null**	

a values — Green at 97%

Groups	Count	Sum	Average	Variance
HA	10	-560.64	-56.064	0.692204
HB	10	-542.74	-54.274	1.097516
HC	10	-534.39	-53.439	0.092988

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	35.97317	2	17.98658	28.66071	2.1E-07	3.354131
Within Groups	16.94437	27	0.627569			
Total	52.91754	29			**Reject Null**	

b values — Green at 97%

Groups	Count	Sum	Average	Variance
HA	10	212.81	21.281	1.994432
HB	10	229.38	22.938	2.073173
HC	10	239.85	23.985	1.079872

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	37.17825	2	18.58912	10.83392	0.000351	3.354131
Within Groups	46.3273	27	1.715826			
Total	83.50555	29			**Reject Null**	

ANOVA: Halftone A Green at around 50%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	814.25	81.425	0.20285
a	10	-159.99	-15.999	0.12341
b	10	105.53	10.553	0.241934

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	50730.95	2	25365.47	133926.7	1.11E-54	3.354131
Within Groups	5.11375	27	0.189398			
Total	50736.06	29				

ANOVA: Halftone B Green at around 50%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	801.28	80.128	0.068951
a	10	-177.97	-17.797	0.074868
b	10	106.55	10.655	0.350539

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	50751.07	2	25375.53	153990.9	1.69E-55	3.354131
Within Groups	4.44922	27	0.164786			
Total	50755.51	29				

ANOVA: Halftone C Green at around 50%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	806.6	80.66	0.135044
a	10	-169.28	-16.928	0.138773
b	10	105.81	10.581	0.559299

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	50637.43	2	25318.72	91171.08	2E-52	3.354131
Within Groups	7.49805	27	0.277706			
Total	50644.93	29				

ANOVA for Green at 50%

L values		Green at 50%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	814.25	81.425	0.20285
HB	10	801.28	80.128	0.068951
HC	10	806.6	80.66	0.135044

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.501527	2	4.250763	31.3443	9.15E-08	3.354131
Within Groups	3.66161	27	0.135615			
Total	12.16314	29			**Reject Null**	

a values		Green at 50%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	-159.99	-15.999	0.12341
HB	10	-177.97	-17.797	0.074868
HC	10	-169.28	-16.928	0.138773

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.17002	2	8.08501	71.96247	1.52E-11	3.354131
Within Groups	3.03346	27	0.11235			
Total	19.20348	29			**Reject Null**	

b values		Green at 50%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	105.53	10.553	0.241934
HB	10	106.55	10.655	0.350539
HC	10	105.81	10.581	0.559299

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.055547	2	0.027773	0.072341	0.930394	3.354131
Within Groups	10.36595	27	0.383924			
Total	10.4215	29			**Cannot Reject Null**	

ANOVA for Green at 10%

L values		Green at 10%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	928.59	92.859	0.083477
HB	10	933.74	93.374	0.046449
HC	10	931.58	93.158	0.020329

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.337607	2	0.668803	13.35342	9.29E-05	3.354131
Within Groups	1.35229	27	0.050085			
Total	2.689897	29			**Reject Null**	

a values		Green at 10%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	-23.91	-2.391	0.073032
HB	10	-19.51	-1.951	0.043677
HC	10	-21.27	-2.127	0.034757

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.980907	2	0.490453	9.714156	0.000664	3.354131
Within Groups	1.36319	27	0.050489			
Total	2.344097	29			**Reject Null**	

b values		Green at 10%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	0.23	0.023	0.034379
HB	10	-3.22	-0.322	0.033929
HC	10	-2.46	-0.246	0.036627

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.657207	2	0.328603	9.394532	0.0008	3.354131
Within Groups	0.94441	27	0.034978			
Total	1.601617	29			**Reject Null**	

ANOVA for Green at 5%

L values		Green at 5%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	934.99	93.499	0.083388
HB	10	944.33	94.433	0.03789
HC	10	943.42	94.342	0.014596

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.304287	2	2.652143	58.5577	1.52E-10	3.354131
Within Groups	1.22286	27	0.045291			
Total	6.527147	29			**Reject Null**	

a values		Green at 5%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	-14.63	-1.463	0.049957
HB	10	-3	-0.3	0.0182
HC	10	-4.73	-0.473	0.026846

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.875327	2	3.937663	124.3444	2.39E-14	3.354131
Within Groups	0.85502	27	0.031667			
Total	8.730347	29			**Reject Null**	

b values		Green at 5%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	-6.58	-0.658	0.039084
HB	10	-18.37	-1.837	0.018957
HC	10	-17.55	-1.755	0.023783

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.667247	2	4.333623	158.8874	1.17E-15	3.354131
Within Groups	0.73642	27	0.027275			
Total	9.403667	29			**Reject Null**	

3-color Overprints

ANOVAs for 3-color Black

ANOVA: Halftone A 3-color Black at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	373.02	37.302	0.03564
a	10	104.44	10.444	0.283227
b	10	12.43	1.243	0.123668

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7020.873	2	3510.437	23797.72	1.49E-44	3.354131
Within Groups	3.98281	27	0.147511			
Total	7024.856	29				

ANOVA: Halftone B 3-color Black at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	357.9	35.79	0.179133
a	10	124.1	12.41	0.552778
b	10	33.75	3.375	0.297161

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5596.626	2	2798.313	8157.775	2.78E-38	3.354131
Within Groups	9.26165	27	0.343024			
Total	5605.888	29				

ANOVA: Halftone C 3-color Black at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	371.61	37.161	0.118677
a	10	99.48	9.948	0.079729
b	10	40.11	4.011	0.148077

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6249.059	2	3124.53	27053.59	2.64E-45	3.354131
Within Groups	3.11834	27	0.115494			
Total	6252.178	29				

ANOVA for 3-color Black at 97%

L values		3-color Black at 97%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	373.02	37.302	0.03564
HB	10	357.9	35.79	0.179133
HC	10	371.61	37.161	0.118677

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13.95222	2	6.97611	62.76302	7.05E-11	3.354131
Within Groups	3.00105	27	0.11115			
Total	16.95327	29			**Reject Null**	

a values		3-color Black at 97%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	104.44	10.444	0.283227
HB	10	124.1	12.41	0.552778
HC	10	99.48	9.948	0.079729

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	33.90872	2	16.95436	55.54355	2.7E-10	3.354131
Within Groups	8.2416	27	0.305244			
Total	42.15032	29			**Reject Null**	

b values		3-color Black at 97%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	12.43	1.243	0.123668

HB	10	33.75	3.375	0.297161
HC	10	40.11	4.011	0.148077

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	42.03915	2	21.01957	110.8422	9.6E-14	3.354131
Within Groups	5.12015	27	0.189635			
Total	47.1593	29			**Reject Null**	

ANOVA: Halftone A 3-color Black at around 50%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	703.3	70.33	0.1758
a	10	25.28	2.528	0.031284
b	10	17.13	1.713	0.056401

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	31020.23	2	15510.11	176595.4	2.66E-56	3.354131
Within Groups	2.37137	27	0.087829			
Total	31022.6	29				

ANOVA: Halftone B 3-color Black at around 50%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
L	10	683.67	68.367	0.186846
a	10	33.14	3.314	0.134716
b	10	20.88	2.088	0.183618

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28754.34	2	14377.17	85378.68	4.85E-52	3.354131
Within Groups	4.54661	27	0.168393			
Total	28758.89	29				

ANOVA: Halftone C 3-color Black at around 50%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	709.38	70.938	0.190196
a	10	30.83	3.083	0.081512
b	10	20.61	2.061	0.107099

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	31164.62	2	15582.31	123405.8	3.36E-54	3.354131
Within Groups	3.40926	27	0.126269			
Total	31168.03	29				

ANOVA for 3-color Black at 50%

L values — 3-color Black at 50%

Groups	Count	Sum	Average	Variance
HA	10	703.3	70.33	0.1758
HB	10	683.67	68.367	0.186846
HC	10	709.38	70.938	0.190196

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	36.11025	2	18.05512	97.97638	4.19E-13	3.354131
Within Groups	4.97557	27	0.18428			
Total	41.08582	29			**Reject Null**	

a values — 3-color Black at 50%

Groups	Count	Sum	Average	Variance
HA	10	25.28	2.528	0.031284
HB	10	33.14	3.314	0.134716
HC	10	30.83	3.083	0.081512

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3.26394	2	1.63197	19.78048	5.13E-06	3.354131
Within Groups	2.22761	27	0.082504			

Total	5.49155	29			**Reject Null**	

b values		3-color Black at 50%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	17.13	1.713	0.056401
HB	10	20.88	2.088	0.183618
HC	10	20.61	2.061	0.107099

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.87486	2	0.43743	3.780532	0.035685	3.354131
Within Groups	3.12406	27	0.115706			
Total	3.99892	29			**Reject Null**	

<u>ANOVA for 3-color Black at 10%</u>

L values		3-color Black at 10%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	906.78	90.678	0.038151
HB	10	913.33	91.333	0.046334
HC	10	919.08	91.908	0.03744

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.575167	2	3.787583	93.19416	7.58E-13	3.354131
Within Groups	1.09733	27	0.040642			
Total	8.672497	29			**Reject Null**	

a values		3-color Black at 10%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	10.85	1.085	0.008317
HB	10	9.75	0.975	0.004828
HC	10	9.25	0.925	0.008361

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.134	2	0.067	9.346422	0.000823	3.354131
Within Groups	0.19355	27	0.007169			

Total	0.32755	29			**Reject Null**	

b values		3-color Black at 10%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	-11.94	-1.194	0.020804
HB	10	-17.17	-1.717	0.040001
HC	10	-17.87	-1.787	0.027379

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.10026	2	1.05013	35.72501	2.6E-08	3.354131
Within Groups	0.79366	27	0.029395			
Total	2.89392	29			**Reject Null**	

ANOVA for 3-color Black at 5%

L values		3-color Black at 5%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	929.9	92.99	0.179578
HB	10	941.43	94.143	0.021068
HC	10	940.19	94.019	0.024499

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.012087	2	4.006043	53.37964	4.15E-10	3.354131
Within Groups	2.0263	27	0.075048			
Total	10.03839	29			**Reject Null**	

a values		3-color Black at 5%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	10	9.75	0.975	0.005161
HB	10	8.64	0.864	0.003004
HC	10	8.3	0.83	0.000867

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.115007	2	0.057503	19.0994	6.78E-06	3.354131
Within Groups	0.08129	27	0.003011			

Total	0.196297	29			Reject Null	

b values 3-color Black at 5%

Groups	Count	Sum	Average	Variance
HA	10	-17.99	-1.799	0.009432
HB	10	-24.08	-2.408	0.003751
HC	10	-23.86	-2.386	0.01076

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.386447	2	1.193223	149.5059	2.48E-15	3.354131
Within Groups	0.21549	27	0.007981			
Total	2.601937	29			**Reject Null**	

4-color Overprints

ANOVAs for 4-color Black

ANOVA: Halftone A 4-color Black at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	252.45	25.245	18.18178
a	10	26.41	2.641	6.716143
b	10	-9.12	-0.912	1.008507

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4025.844	2	2012.922	233.0991	9.28E-18	3.354131
Within Groups	233.1579	27	8.635478			
Total	4259.002	29				

ANOVA: Halftone B 4-color Black at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	225.73	22.573	22.66971
a	10	32.96	3.296	11.29569
b	10	6.35	0.635	1.013117

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2866.532	2	1433.266	122.9268	2.74E-14	3.354131
Within Groups	314.8067	27	11.65951			
Total	3181.338	29				

ANOVA: Halftone C 4-color Black at around 97%

SUMMARY

Groups	Count	Sum	Average	Variance
L	10	279.09	27.909	24.44168
a	10	22.67	2.267	16.50993
b	10	20.61	2.061	1.325454

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4418.912	2	2209.456	156.784	1.38E-15	3.354131
Within Groups	380.4936	27	14.09236			
Total	4799.406	29				

ANOVA: Halftone A 4-color Black at around 50%

SUMMARY

Groups	Count	Sum	Average	Variance
L	40	2615.97	65.39925	0.079387
a	40	-89.34	-2.2335	0.028039
b	40	-50.17	-1.25425	0.082076

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	120237.8	2	60118.91	951742.2	4.3E-247	3.073765
Within Groups	7.390565	117	0.063167			
Total	120245.2	119				

ANOVA: Halftone B 4-color Black at around 50%

SUMMARY

Groups	Count	Sum	Average	Variance
L	40	2542.73	63.56825	0.056189
a	40	-81.85	-2.04625	0.057229
b	40	-50.88	-1.272	0.060729

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	113468.3	2	56734.13	977345.9	9.1E-248	3.073765
Within Groups	6.791755	117	0.058049			
Total	113475.1	119				

ANOVA: Halftone C 4-color Black at around 50%

SUMMARY

Groups	Count	Sum	Average	Variance
L	40	2611.07	65.27675	0.093905
a	40	-82.05	-2.05125	0.039016
b	40	-28.09	-0.70225	0.042485

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	118508.1	2	59254.05	1013436	1.1E-248	3.073765
Within Groups	6.840813	117	0.058468			
Total	118514.9	119				

ANOVA for 4-color Black at 50%

L values		4-color Black at 50%		
Groups	*Count*	*Sum*	*Average*	*Variance*
HA	40	2615.97	65.39925	0.079387
HB	40	2542.73	63.56825	0.056189
HC	40	2611.07	65.27675	0.093905

Source of Variation	SS	df	MS	F	P-value	F crit

Between Groups	83.82053	2	41.91026	547.8936	3.87E-60	3.073765
Within Groups	8.949732	117	0.076493			
Total	92.77026	119			**Reject Null**	

a values

Groups	Count	Sum	Average	Variance
HA	40	-89.34	-2.2335	0.028039
HB	40	-81.85	-2.04625	0.057229
HC	40	-82.05	-2.05125	0.039016

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.910702	2	0.455351	10.99136	4.22E-05	3.073765
Within Groups	4.847085	117	0.041428			
Total	5.757787	119			**Reject Null**	

b values

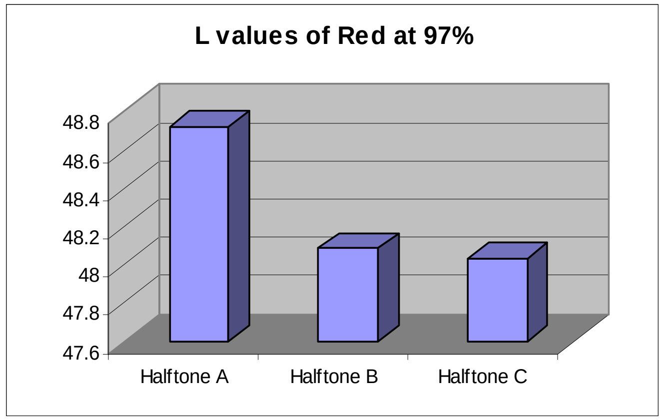
Groups	Count	Sum	Average	Variance
HA	40	-50.17	-1.25425	0.082076
HB	40	-50.88	-1.272	0.060729
HC	40	-28.09	-0.70225	0.042485

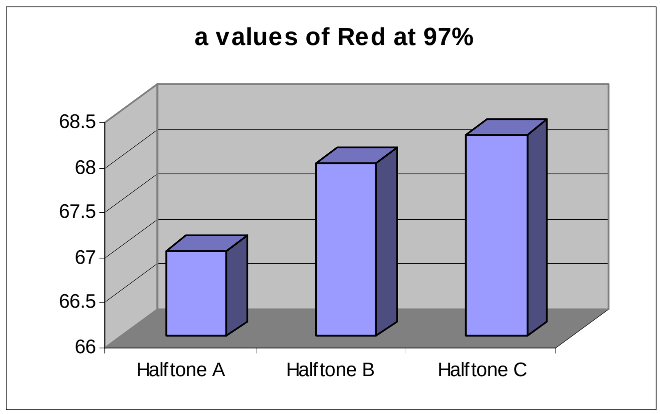
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.395122	2	4.197561	67.96197	2.59E-20	3.073765
Within Groups	7.226315	117	0.061763			
Total	15.62144	119			**Reject Null**	

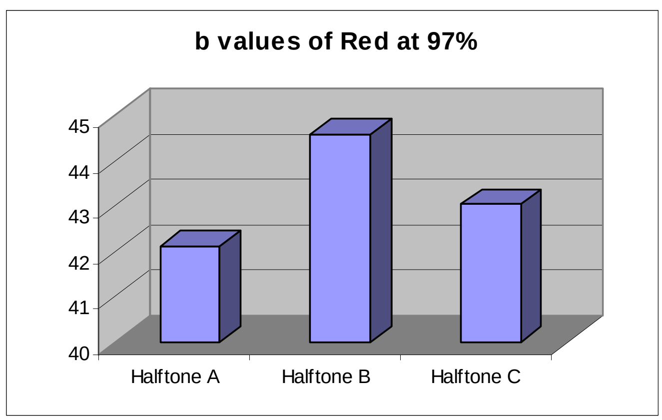
Charts and least squared difference Calculations for Lab Values

Red at 97%

Average of L values	
Halftone A	48.7275
Halftone B	48.0865
Halftone C	48.0315
Average of a values	
Halftone A	66.951
Halftone B	67.9315
Halftone C	68.234
Average of b values	
Halftone A	42.1355
Halftone B	44.615
Halftone C	43.05







Difference determined by lsd

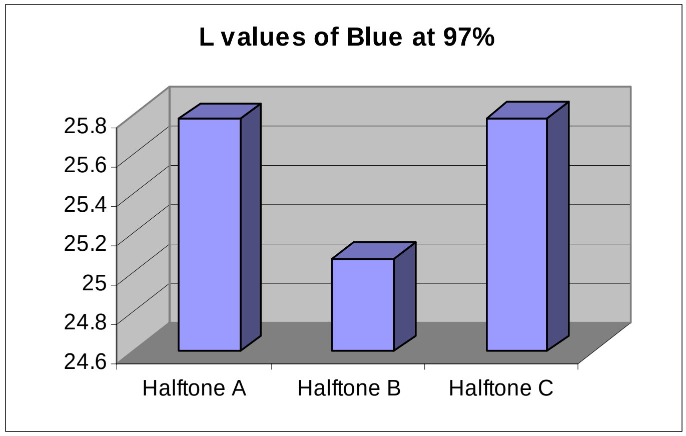
L values		
t=	2.002466	
lsd=	0.102123	
Mean diff		
HA - HB	0.641	**Diff**
HB - HC	0.055	**No Diff**
HA - HC	0.696	**Diff**
a values		
t=	2.002466	
lsd=	0.356974	
Mean diff		
HA - HB	-0.9805	**Diff**
HB - HC	-0.3025	**No Diff**
HA - HC	-1.283	**Diff**
b values		
t=	2.002466	
lsd=	0.211951	
Mean diff		
HA - HB	-2.4795	**Diff**
HB - HC	1.565	**Diff**
HA - HC	-0.9145	**Diff**

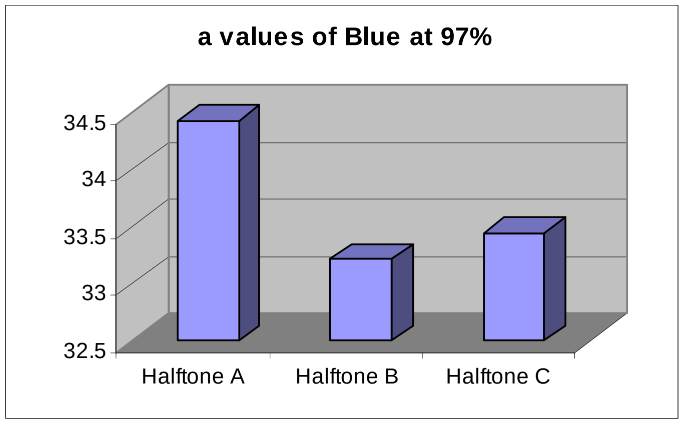
Blue at 97%

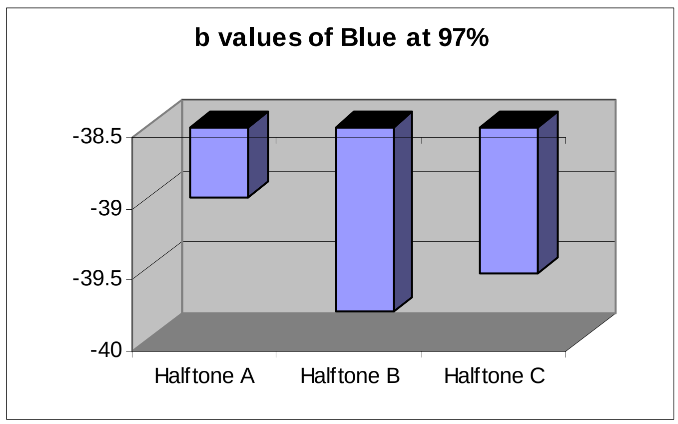
Average of L values	
Halftone A	25.781
Halftone B	25.075
Halftone C	25.787
Average of a values	
Halftone A	34.426
Halftone B	33.214
Halftone C	33.441
Average of b values	
Halftone A	-38.995
Halftone B	-39.811
Halftone C	-39.535

Difference determined by lsd

L values		
t=	2.051829	
lsd=	0.26392	
Mean diff		
HA - HB	0.706	**Diff**
HB - HC	-0.712	**Diff**
HA - HC	-0.006	**No Diff**
a values		
t=	2.051829	
lsd=	0.753078	
Mean diff		
HA - HB	1.212	**Diff**
HB - HC	-0.227	**No Diff**
HA - HC	0.985	**Diff**
b values		
t=	2.051829	
lsd=	0.422357	
Mean diff		
HA - HB	0.816	**Diff**
HB - HC	-0.276	**No Diff**
HA - HC	0.54	**Diff**





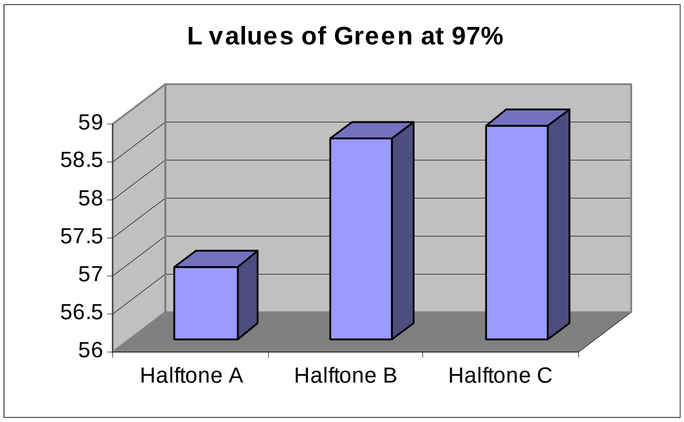


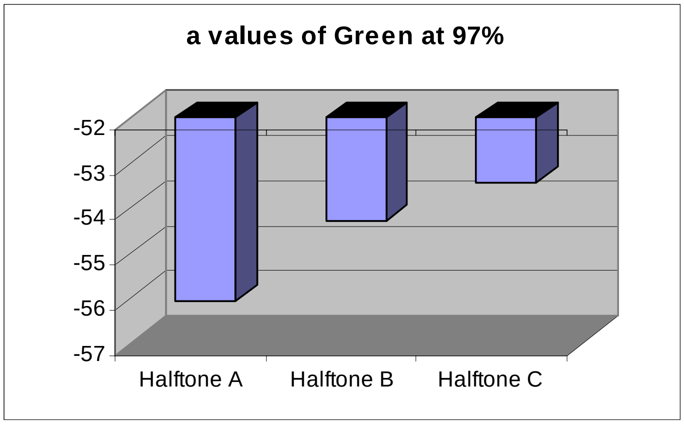
Green at 97%

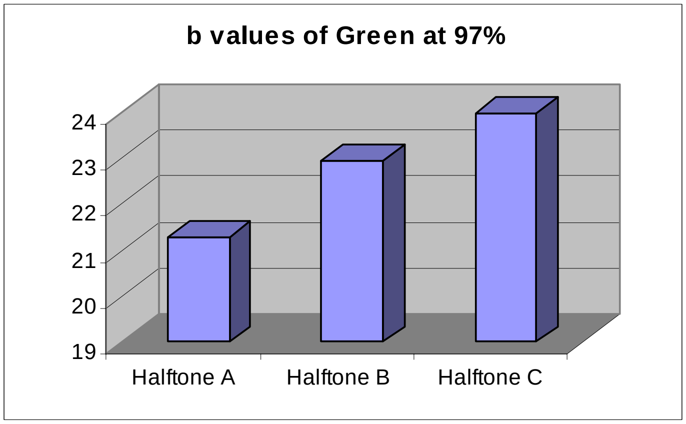
Average of L values	
Halftone A	56.968
Halftone B	58.656
Halftone C	58.827
Average of a values	
Halftone A	-56.064
Halftone B	-54.274
Halftone C	-53.439
Average of b values	
Halftone A	21.281
Halftone B	22.938
Halftone C	23.985

Difference determined by lsd

L values		
t=	2.051829	
lsd=	0.528348	
Mean diff		
HA - HB	-1.688	**Diff**
HB - HC	-0.171	**No Diff**
HA - HC	-1.859	**Diff**
a values		
t=	2.051829	
lsd=	0.726921	
Mean diff		
HA - HB	-1.79	**Diff**
HB - HC	-0.835	**Diff**
HA - HC	-2.625	**Diff**
b values		
t=	2.051829	
lsd=	1.201968	
Mean diff		
HA - HB	-1.657	**Diff**
HB - HC	-1.047	**No Diff**
HA - HC	-2.704	**Diff**

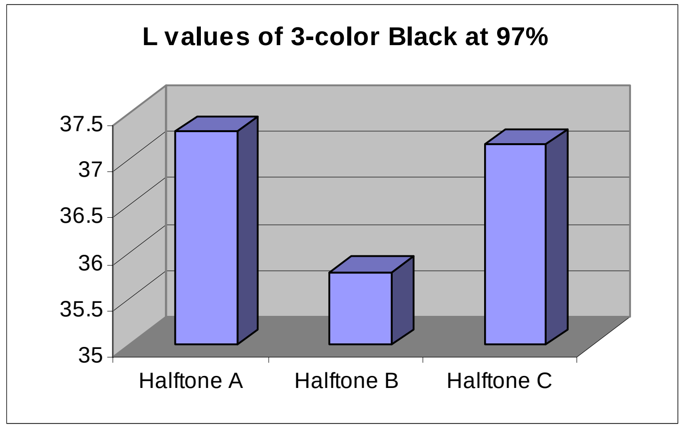


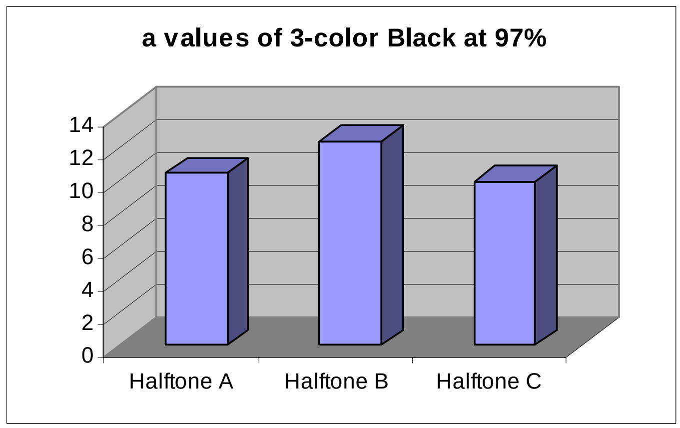


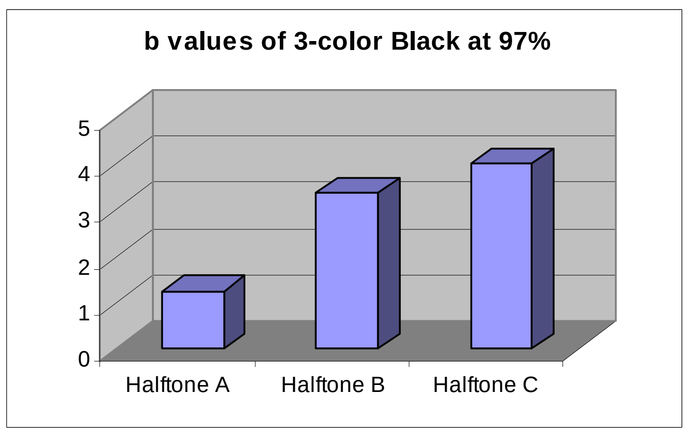


3-color Black at 97%

Average of L values	
Halftone A	37.302
Halftone B	35.79
Halftone C	37.161
Average of a values	
Halftone A	10.444
Halftone B	12.41
Halftone C	9.948
Average of b values	
Halftone A	1.243
Halftone B	3.375
Halftone C	4.011





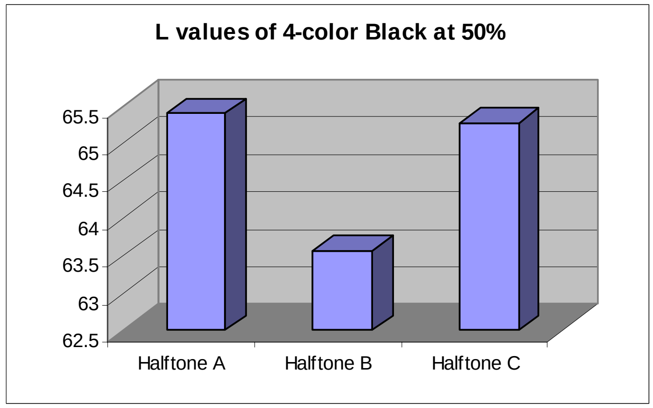


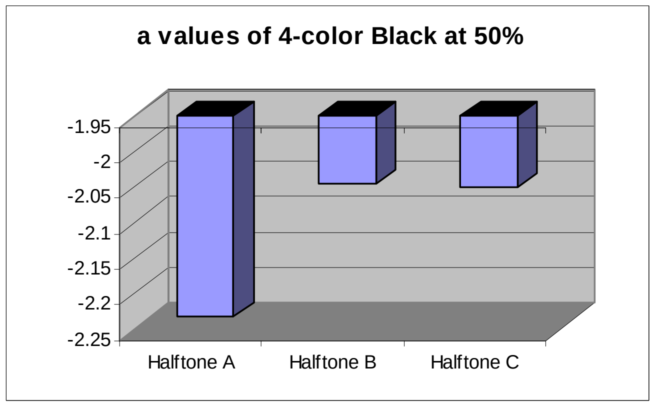
Difference determined by lsd

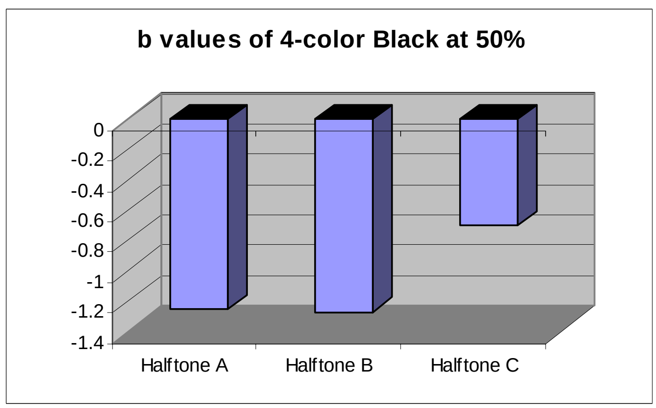
L values		
t=	2.051829	
lsd=	0.305922	
Mean diff		
HA - HB	1.512	**Diff**
HB - HC	-1.371	**Diff**
HA - HC	0.141	**No Diff**
a values		
t=	2.051829	
lsd=	0.506967	
Mean diff		
HA - HB	-1.966	**Diff**
HB - HC	2.462	**Diff**
HA - HC	0.496	**No Diff**
b values		
t=	2.051829	
lsd=	0.399591	
Mean diff		
HA - HB	-2.132	**Diff**
HB - HC	-0.636	**Diff**
HA - HC	-2.768	**Diff**

4-color Black at 50%

Average of L values	
Halftone A	65.39925
Halftone B	63.56825
Halftone C	65.27675
Average of a values	
Halftone A	-2.2335
Halftone B	-2.04625
Halftone C	-2.05125
Average of b values	
Halftone A	-1.25425
Halftone B	-1.272
Halftone C	-0.70225





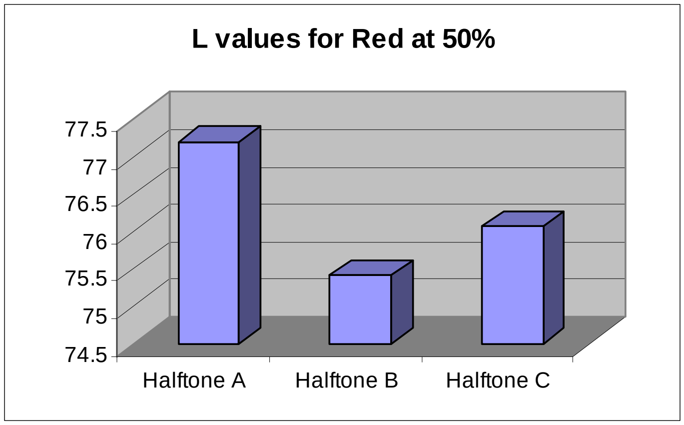


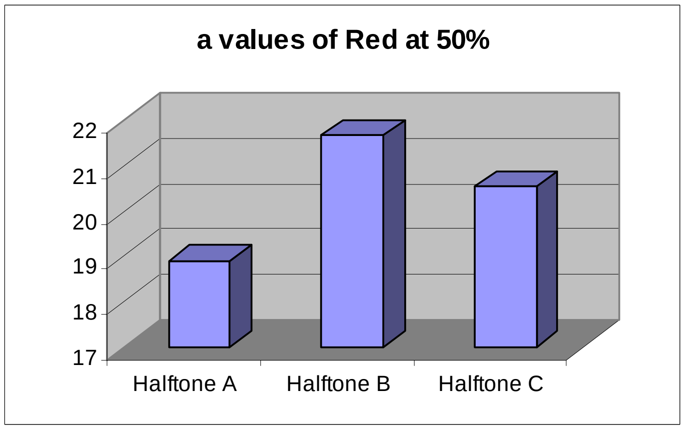
Difference determined by lsd

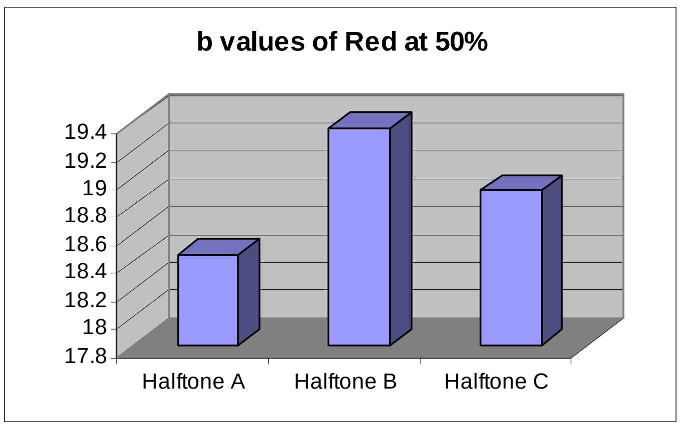
L values		
t=	1.980447	
lsd=	0.122479	
Mean diff		
HA - HB	1.831	**Diff**
HB - HC	-1.7085	**Diff**
HA - HC	0.1225	**Diff**
a values		
t=	1.980447	
lsd=	0.090135	
Mean diff		
HA - HB	-0.18725	**Diff**
HB - HC	0.005	**No Diff**
HA - HC	-0.18225	**Diff**
b values		
t=	1.980447	
lsd=	0.110056	
Mean diff		
HA - HB	0.01775	**No Diff**
HB - HC	-0.56975	**Diff**
HA - HC	-0.552	**Diff**

Red at 50%

Average of L values	
Halftone A	77.207
Halftone B	75.417
Halftone C	76.072
Average of a values	
Halftone A	18.917
Halftone B	21.688
Halftone C	20.552
Average of b values	
Halftone A	18.447
Halftone B	19.358
Halftone C	18.911





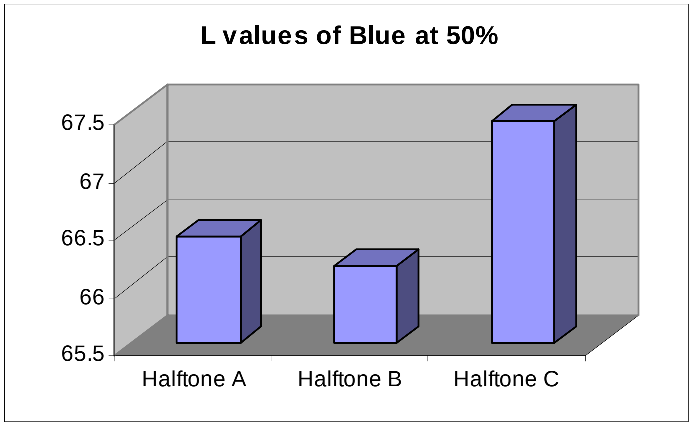


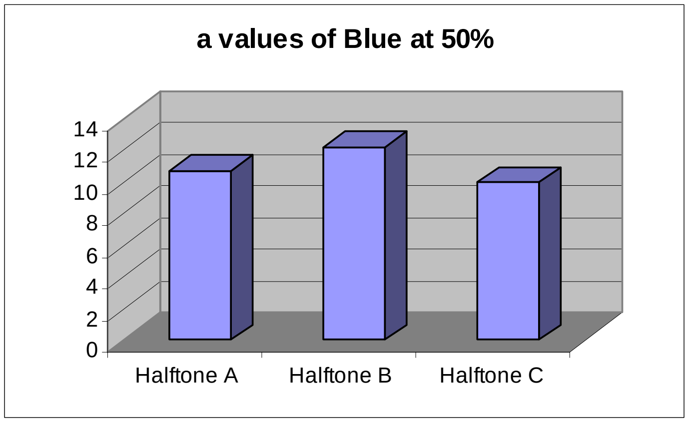
Difference determined by lsd

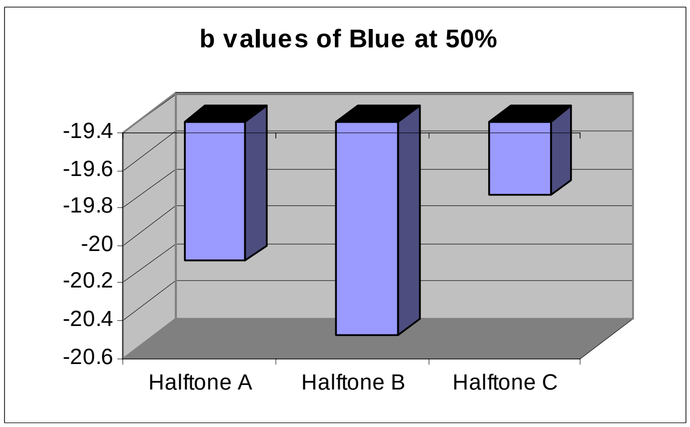
L values		
t=	2.051829	
lsd=	0.429161	
Mean diff		
HA - HB	1.79	**Diff**
HB - HC	-0.655	**Diff**
HA - HC	1.135	**Diff**
a values		
t=	2.051829	
lsd=	0.661406	
Mean diff		
HA - HB	-2.771	**Diff**
HB - HC	1.136	**Diff**
HA - HC	-1.635	**Diff**
b values		
t=	2.051829	
lsd=	0.292669	
Mean diff		
HA - HB	-0.911	**Diff**
HB - HC	0.447	**Diff**
HA - HC	-0.464	**Diff**

Blue at 50%

Average of L values	
Halftone A	66.426
Halftone B	66.17
Halftone C	67.432
Average of a values	
Halftone A	10.744
Halftone B	12.202
Halftone C	9.986
Average of b values	
Halftone A	-20.145
Halftone B	-20.542
Halftone C	-19.797







Difference determined by lsd

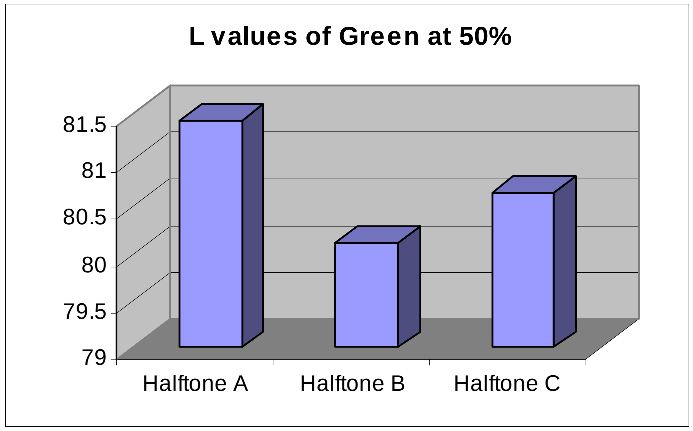
L values		
t=	2.051829	
lsd=	0.443197	
Mean diff		
HA - HB	0.256	**No Diff**
HB - HC	-1.262	**Diff**
HA - HC	-1.006	**Diff**
a values		
t=	2.051829	
lsd=	0.538932	
Mean diff		
HA - HB	-1.458	**Diff**
HB - HC	2.216	**Diff**
HA - HC	0.758	**Diff**
b values		
t=	2.051829	
lsd=	0.305584	
Mean diff		
HA - HB	0.397	**Diff**
HB - HC	-0.745	**Diff**
HA - HC	-0.348	**Diff**

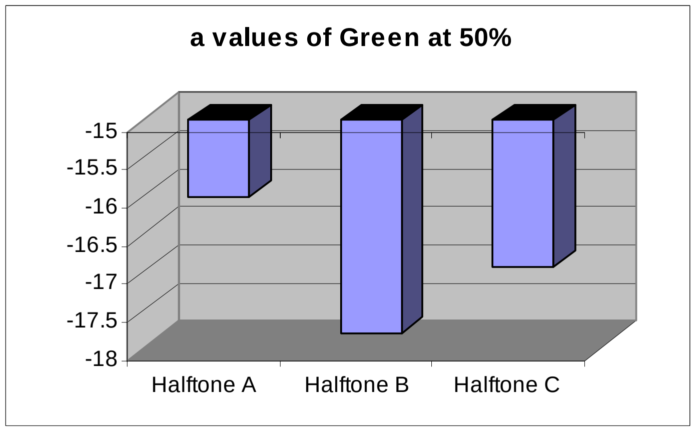
Green at 50%

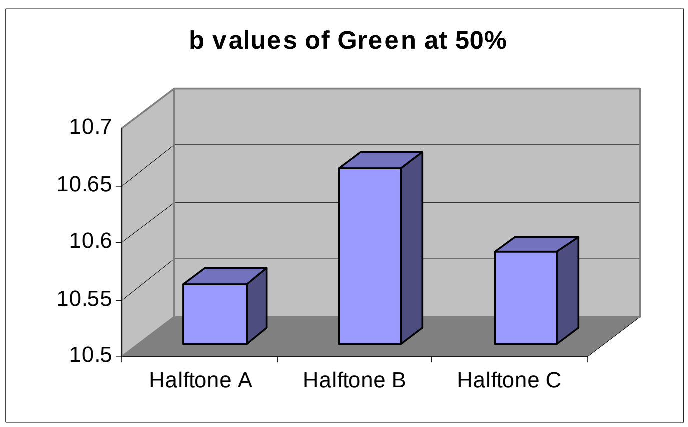
Average of L values	
Halftone A	81.425
Halftone B	80.128
Halftone C	80.66
Average of a values	
Halftone A	-15.999
Halftone B	-17.797
Halftone C	-16.928
Average of b values	
Halftone A	10.553
Halftone B	10.655
Halftone C	10.581

Difference determined by lsd

L values		
t=	2.051829	
lsd=	0.337917	
Mean diff		
HA - HB	1.297	**Diff**
HB - HC	-0.532	**Diff**
HA - HC	0.765	**Diff**
a values		
t=	2.051829	
lsd=	0.30757	
Mean diff		
HA - HB	1.798	**Diff**
HB - HC	-0.869	**Diff**
HA - HC	0.929	**Diff**
b values		
t=	2.051829	
lsd=	0.568563	
Mean diff		
HA - HB	-0.102	**No Diff**
HB - HC	0.074	**No Diff**
HA - HC	-0.028	**No Diff**





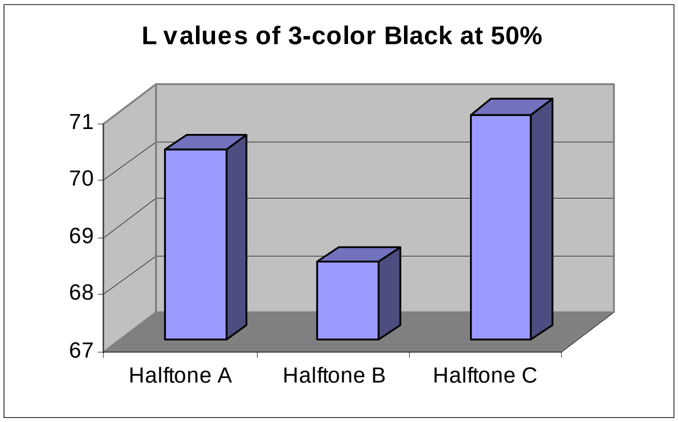


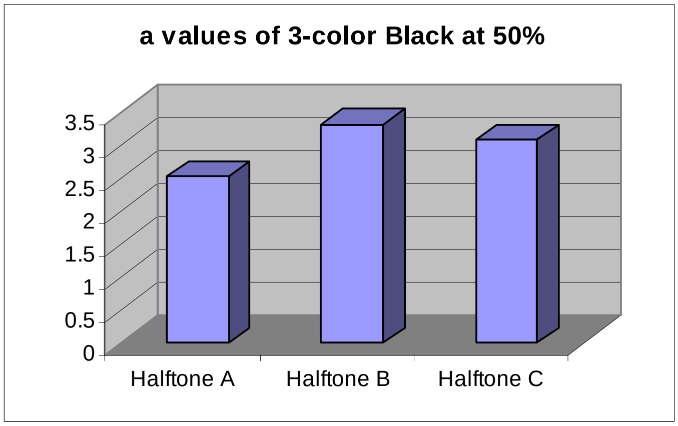
3-color Black at 50%

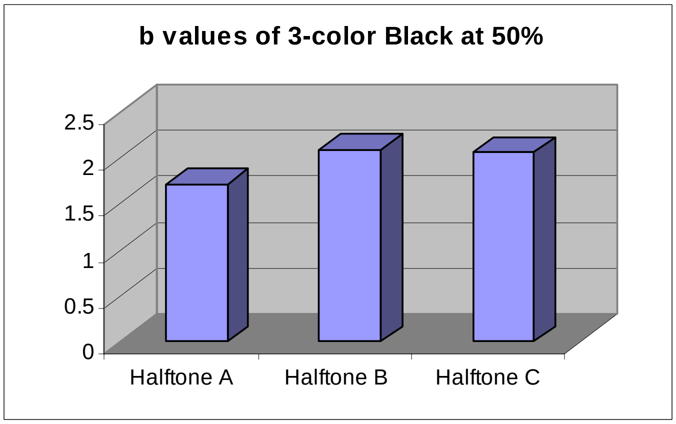
Average of L values	
Halftone A	70.33
Halftone B	68.367
Halftone C	70.938
Average of a values	
Halftone A	2.528
Halftone B	3.314
Halftone C	3.083
Average of b values	
Halftone A	1.713
Halftone B	2.088
Halftone C	2.061

Difference determined by lsd

L values		
t=	2.051829	
lsd=	0.393909	
Mean diff		
HA - HB	1.963	**Diff**
HB - HC	-2.571	**Diff**
HA - HC	-0.608	**Diff**
a values		
t=	2.051829	
lsd=	0.263569	
Mean diff		
HA - HB	-0.786	**Diff**
HB - HC	0.231	**No Diff**
HA - HC	-0.555	**Diff**
b values		
t=	2.051829	
lsd=	0.312129	
Mean diff		
HA - HB	-0.375	**Diff**
HB - HC	0.027	**No Diff**
HA - HC	-0.348	**Diff**

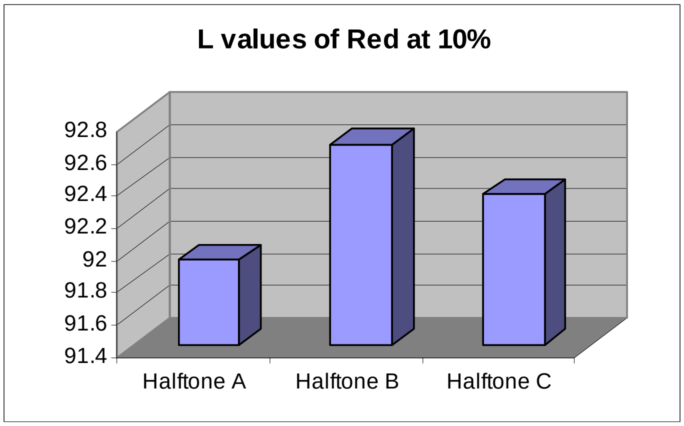


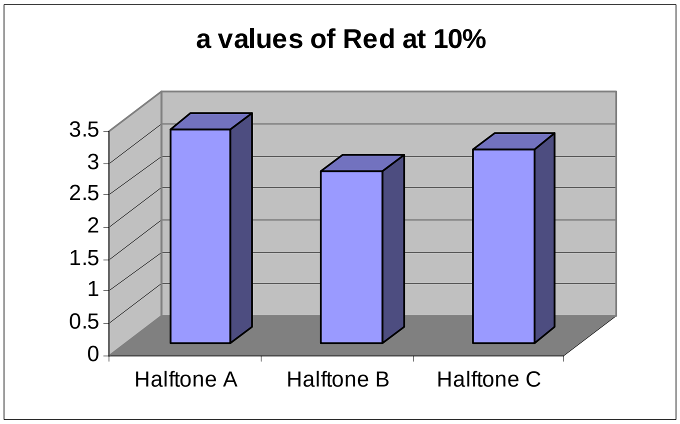


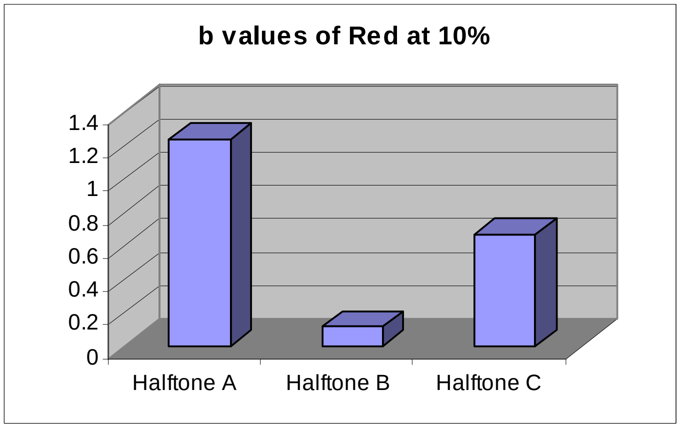


Red at 10%

Average of L values	
Halftone A	91.931
Halftone B	92.654
Halftone C	92.337
Average of a values	
Halftone A	3.349
Halftone B	2.704
Halftone C	3.034
Average of b values	
Halftone A	1.244
Halftone B	0.117
Halftone C	0.675





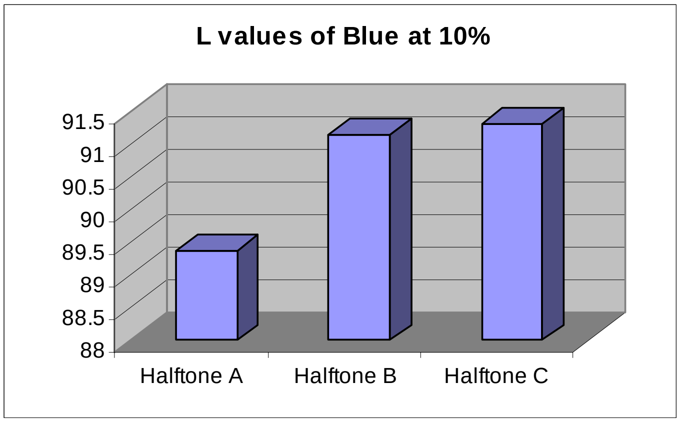


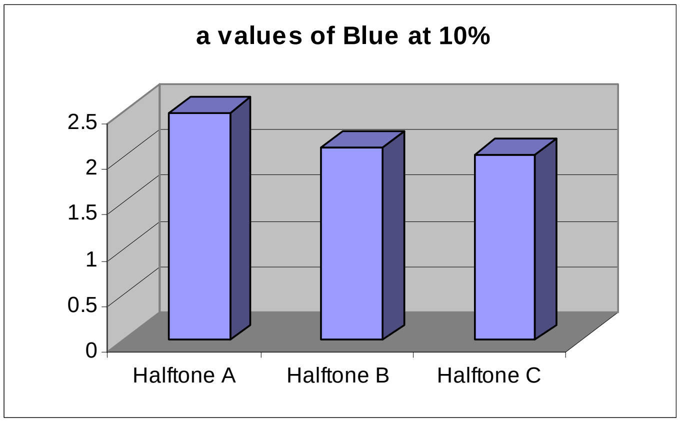
Difference determined by lsd

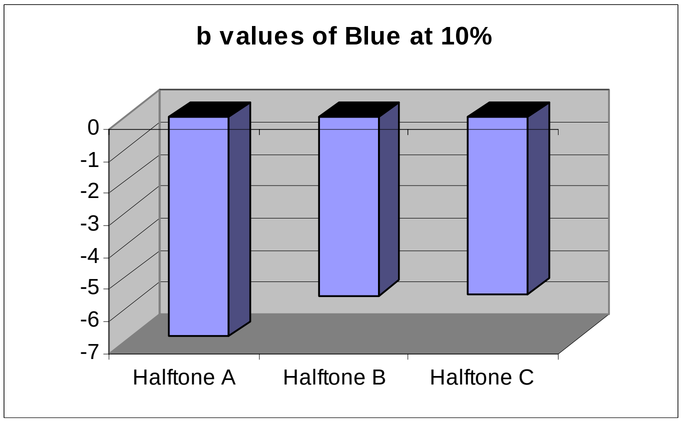
L values		
t=	2.051829	
lsd=	0.111735	
Mean diff		
HA - HB	-0.723	**Diff**
HB - HC	0.317	**Diff**
HA - HC	-0.406	**Diff**
a values		
t=	2.051829	
lsd=	0.1007	
Mean diff		
HA - HB	0.645	**Diff**
HB - HC	-0.33	**Diff**
HA - HC	0.315	**Diff**
b values		
t=	2.051829	
lsd=	0.114186	
Mean diff		
HA - HB	1.127	**Diff**
HB - HC	-0.558	**Diff**
HA - HC	0.569	**Diff**

Blue at 10%

Average of L values	
Halftone A	89.366
Halftone B	91.146
Halftone C	91.315
Average of a values	
Halftone A	2.481
Halftone B	2.115
Halftone C	2.031
Average of b values	
Halftone A	-6.84
Halftone B	-5.572
Halftone C	-5.509





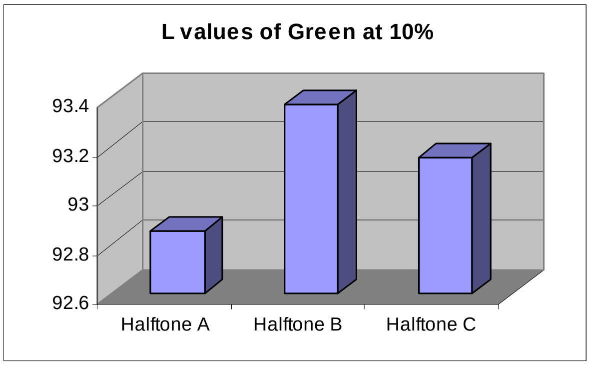


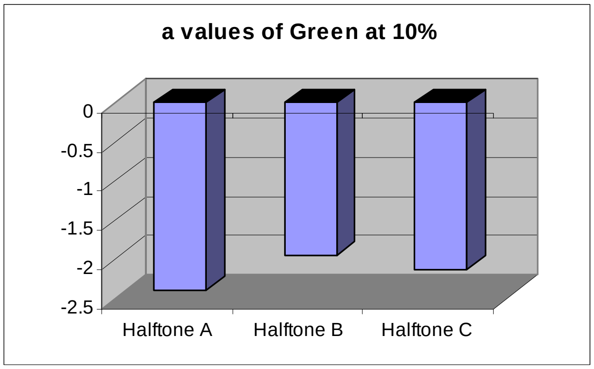
Difference determined by lsd

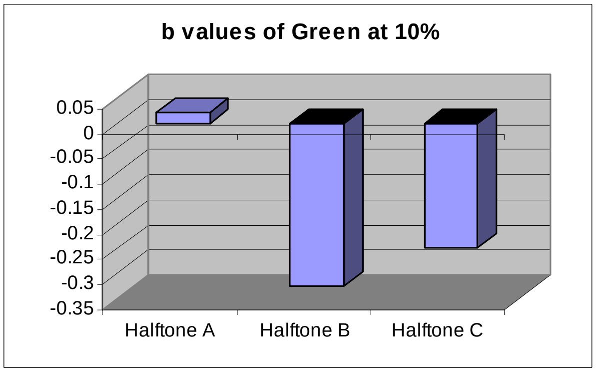
L values		
t=	2.051829	
lsd=	0.235481	
Mean diff		
HA - HB	-1.78	**Diff**
HB - HC	-0.169	**No Diff**
HA - HC	-1.949	**Diff**
a values		
t=	2.051829	
lsd=	0.119515	
Mean diff		
HA - HB	0.366	**Diff**
HB - HC	0.084	**No Diff**
HA - HC	0.45	**Diff**
b values		
t=	2.051829	
lsd=	0.207739	
Mean diff		
HA - HB	-1.268	**Diff**
HB - HC	-0.063	**No Diff**
HA - HC	-1.331	**Diff**

Green at 10%

Average of L values	
Halftone A	92.859
Halftone B	93.374
Halftone C	93.158
Average of a values	
Halftone A	-2.391
Halftone B	-1.951
Halftone C	-2.127
Average of b values	
Halftone A	0.023
Halftone B	-0.322
Halftone C	-0.246





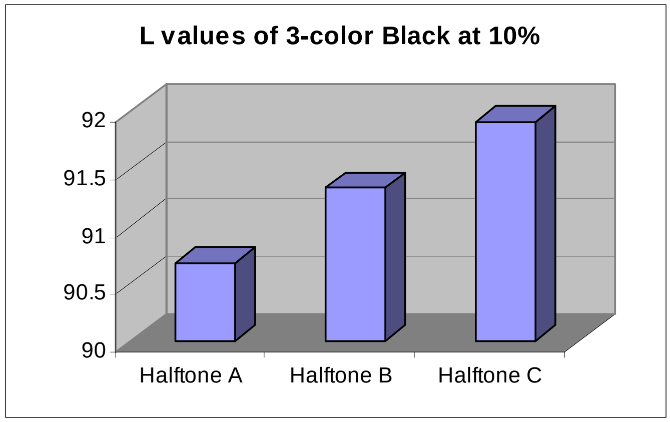


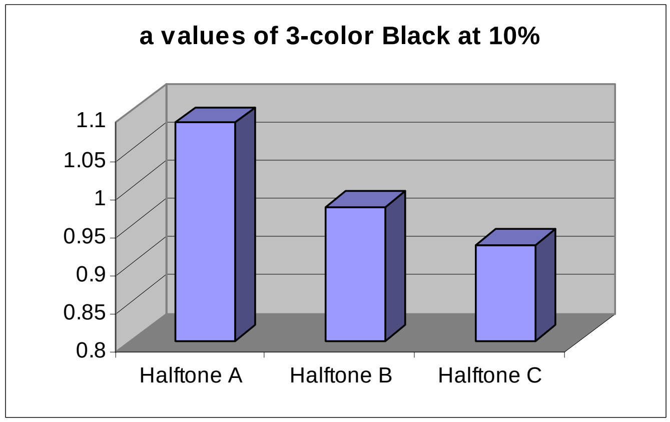
Difference determined by lsd

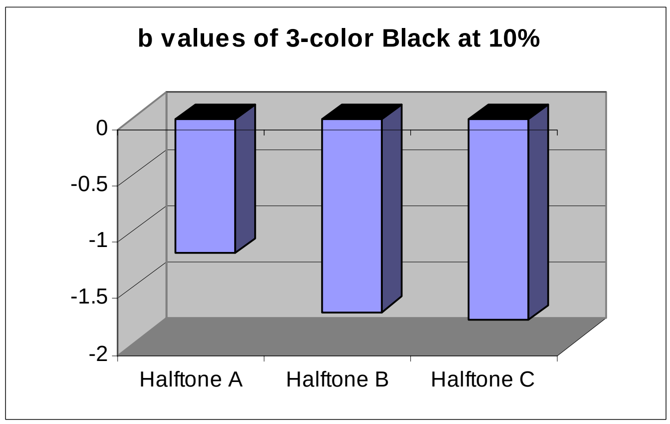
L values		
t=	2.051829	
lsd=	0.205357	
Mean diff		
HA - HB	-0.515	**Diff**
HB - HC	0.216	**Diff**
HA - HC	-0.299	**Diff**
a values		
t=	2.051829	
lsd=	0.206183	
Mean diff		
HA - HB	-0.44	**Diff**
HB - HC	0.176	**No Diff**
HA - HC	-0.264	**Diff**
b values		
t=	2.051829	
lsd=	0.171615	
Mean diff		
HA - HB	0.345	**Diff**
HB - HC	-0.076	**No Diff**
HA - HC	0.269	**Diff**

3-color Black at 10%

Average of L values	
Halftone A	90.678
Halftone B	91.333
Halftone C	91.908
Average of a values	
Halftone A	1.085
Halftone B	0.975
Halftone C	0.925
Average of b values	
Halftone A	-1.194
Halftone B	-1.717
Halftone C	-1.787





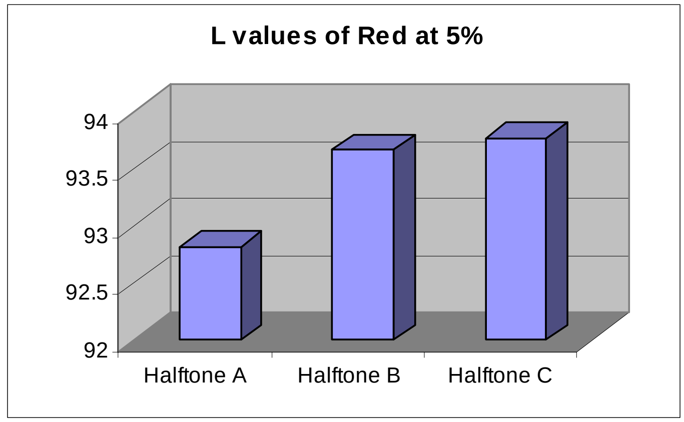


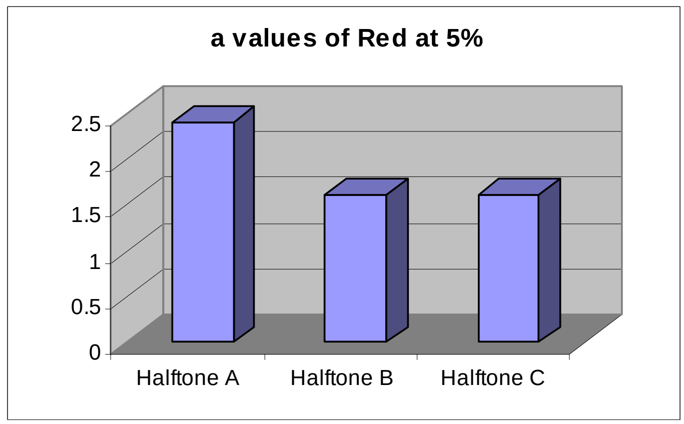
Difference determined by lsd

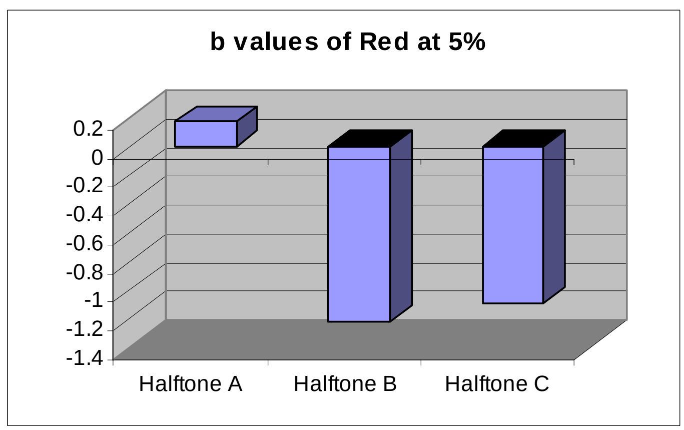
L values		
t=	2.051829	
lsd=	0.184988	
Mean diff		
HA - HB	-0.655	**Diff**
HB - HC	-0.575	**Diff**
HA - HC	-1.23	**Diff**
a values		
t=	2.051829	
lsd=	0.077691	
Mean diff		
HA - HB	0.11	**Diff**
HB - HC	0.05	**No Diff**
HA - HC	0.16	**Diff**
b values		
t=	2.051829	
lsd=	0.157323	
Mean diff		
HA - HB	0.523	**Diff**
HB - HC	0.07	**No Diff**
HA - HC	0.593	**Diff**

Red at 5%

Average of L values	
Halftone A	92.814
Halftone B	93.665
Halftone C	93.771
Average of a values	
Halftone A	2.402
Halftone B	1.622
Halftone C	1.621
Average of b values	
Halftone A	0.175
Halftone B	-1.219
Halftone C	-1.087





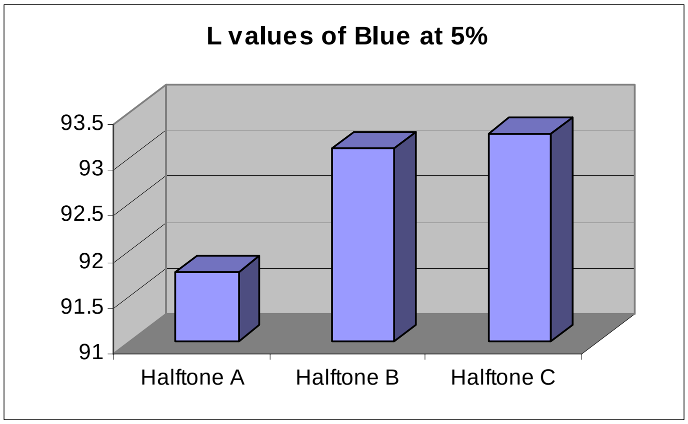


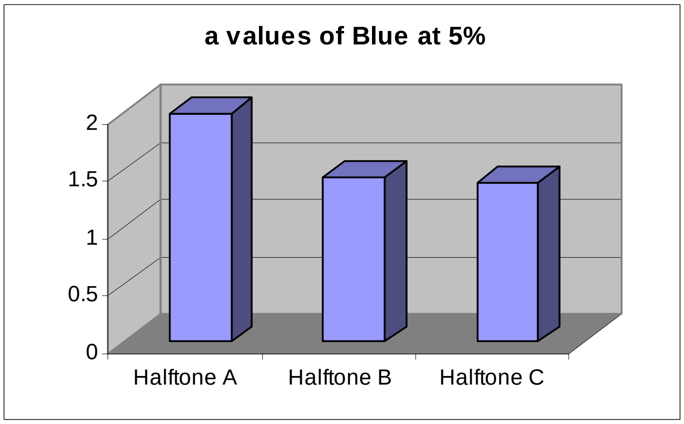
Difference determined by lsd

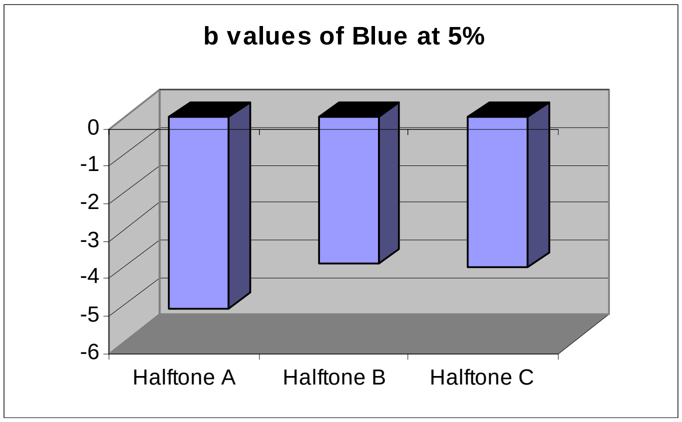
L values		
t=	2.051829	
lsd=	0.195282	
Mean diff		
HA - HB	-0.934	**Diff**
HB - HC	0.091	**No Diff**
HA - HC	-0.843	**Diff**
a values		
t=	2.051829	
lsd=	0.139253	
Mean diff		
HA - HB	0.78	**Diff**
HB - HC	0.001	**No Diff**
HA - HC	0.781	**Diff**
b values		
t=	2.051829	
lsd=	0.136829	
Mean diff		
HA - HB	1.394	**Diff**
HB - HC	-0.132	**No Diff**
HA - HC	1.262	**Diff**

Blue at 5%

Average of L values	
Halftone A	91.759
Halftone B	93.116
Halftone C	93.274
Average of a values	
Halftone A	1.992
Halftone B	1.439
Halftone C	1.387
Average of b values	
Halftone A	-5.119
Halftone B	-3.933
Halftone C	-4.008





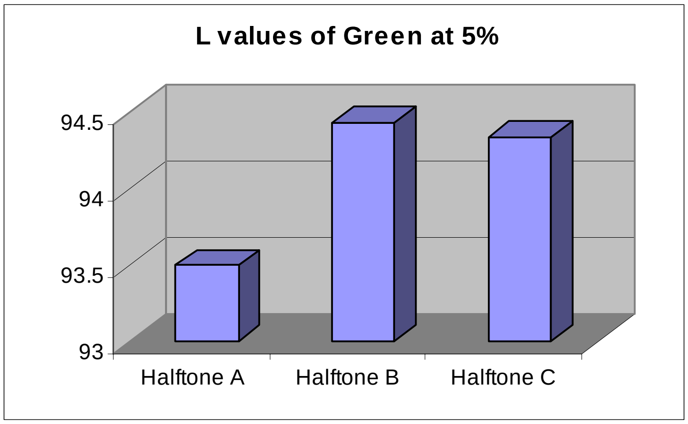


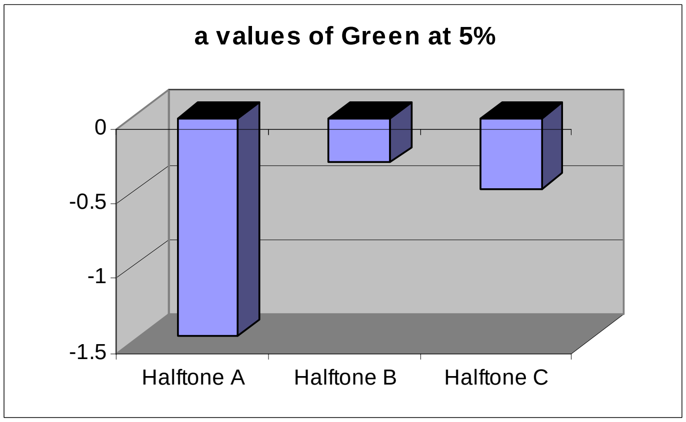
Difference determined by lsd

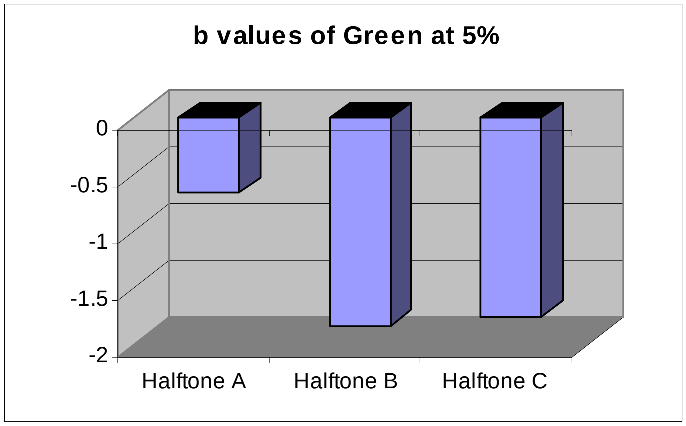
L values		
t=	2.051829	
lsd=	0.271952	
Mean diff		
HA - HB	-1.357	**Diff**
HB - HC	-0.158	**No Diff**
HA - HC	-1.515	**Diff**
a values		
t=	2.051829	
lsd=	0.079929	
Mean diff		
HA - HB	0.553	**Diff**
HB - HC	0.052	**No Diff**
HA - HC	0.605	**Diff**
b values		
t=	2.051829	
lsd=	0.199782	
Mean diff		
HA - HB	-1.186	**Diff**
HB - HC	0.075	**No Diff**
HA - HC	-1.111	**Diff**

Green at 5%

Average of L values	
Halftone A	93.499
Halftone B	94.433
Halftone C	94.342
Average of a values	
Halftone A	-1.463
Halftone B	-0.3
Halftone C	-0.473
Average of b values	
Halftone A	-0.658
Halftone B	-1.837
Halftone C	-1.755







Difference determined by lsd

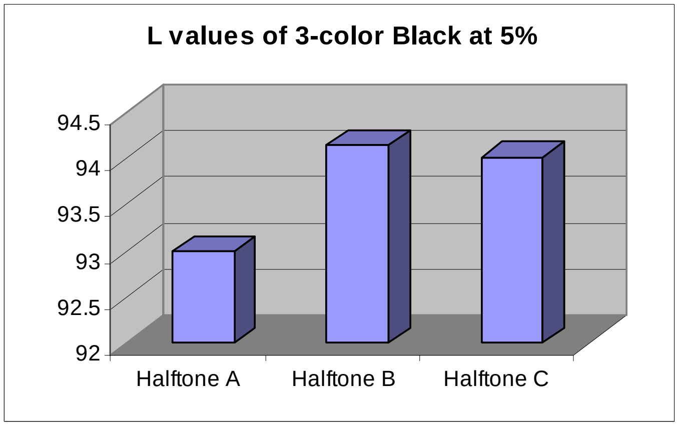
L values		
t=	2.051829	
lsd=	0.195282	
Mean diff		
HA - HB	-0.934	**Diff**
HB - HC	0.091	**No Diff**
HA - HC	-0.843	**Diff**
a values		
t=	2.051829	
lsd=	0.163291	
Mean diff		
HA - HB	-1.163	**Diff**
HB - HC	0.173	**Diff**
HA - HC	-0.99	**Diff**
b values		
t=	2.051829	
lsd=	0.151543	
Mean diff		
HA - HB	1.179	**Diff**
HB - HC	-0.082	**No Diff**
HA - HC	1.097	**Diff**

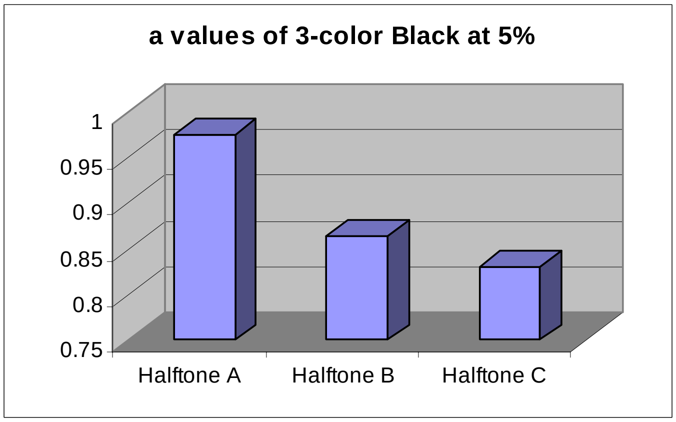
3-color Black at 5%

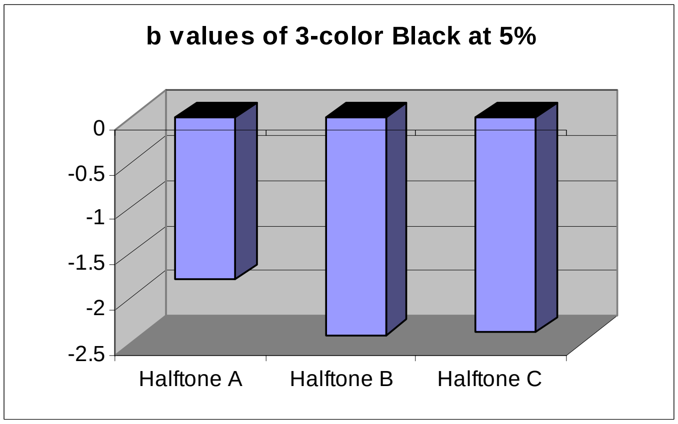
Average of L values	
Halftone A	92.99
Halftone B	94.143
Halftone C	94.019
Average of a values	
Halftone A	0.975
Halftone B	0.864
Halftone C	0.83
Average of b values	
Halftone A	-1.799
Halftone B	-2.408
Halftone C	-2.386

Difference determined by lsd

L values		
t=	2.051829	
lsd=	0.251377	
Mean diff		
HA - HB	-1.153	**Diff**
HB - HC	0.124	**No Diff**
HA - HC	-1.029	**Diff**
a values		
t=	2.051829	
lsd=	0.050349	
Mean diff		
HA - HB	0.111	**Diff**
HB - HC	0.034	**No Diff**
HA - HC	0.145	**Diff**
b values		
t=	2.051829	
lsd=	0.081976	
Mean diff		
HA - HB	0.609	**Diff**
HB - HC	-0.022	**No Diff**
HA - HC	0.587	**Diff**

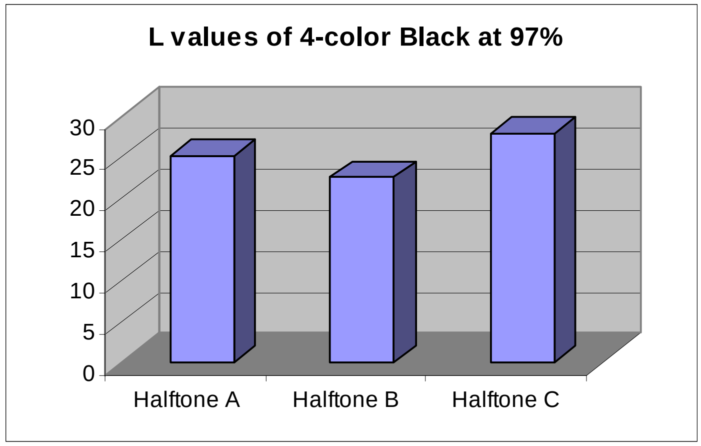


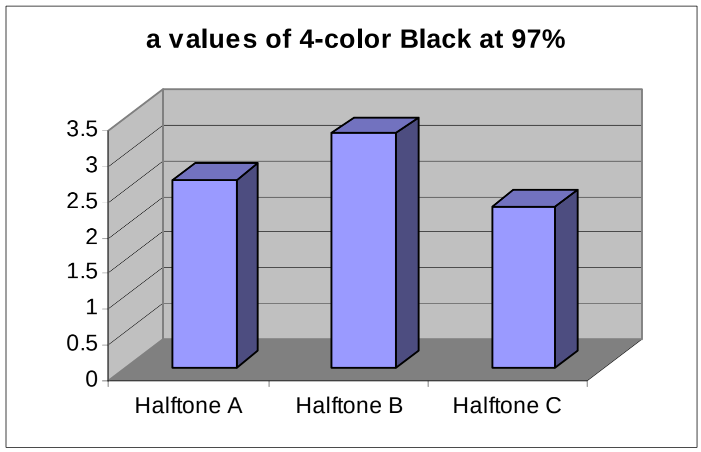


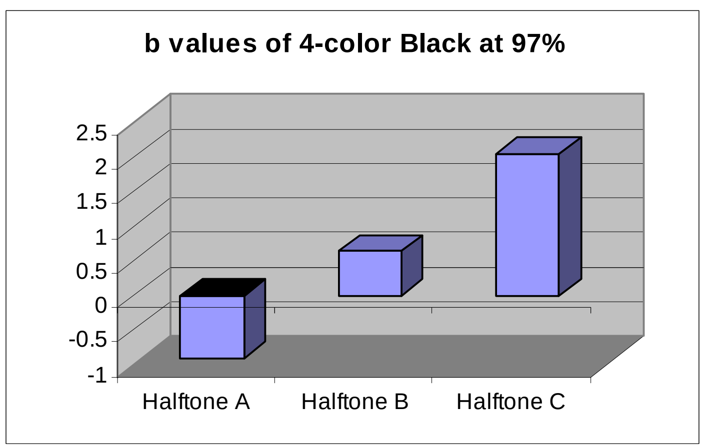


4-color Black at 97%

Average of L values	
Halftone A	25.245
Halftone B	22.573
Halftone C	27.909
Average of a values	
Halftone A	2.641
Halftone B	3.296
Halftone C	2.267
Average of b values	
Halftone A	-0.912
Halftone B	0.635
Halftone C	2.061

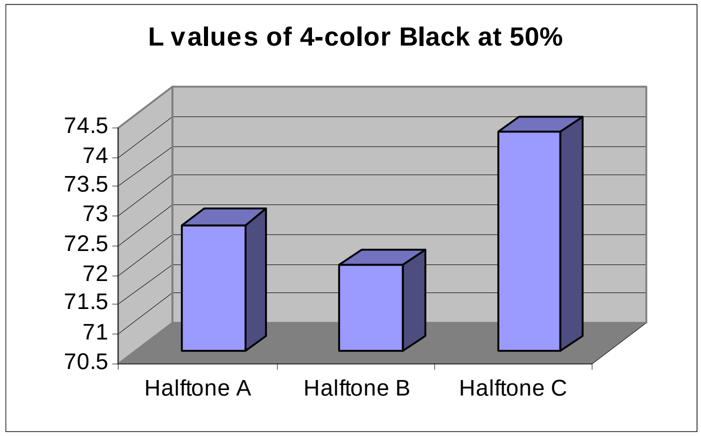


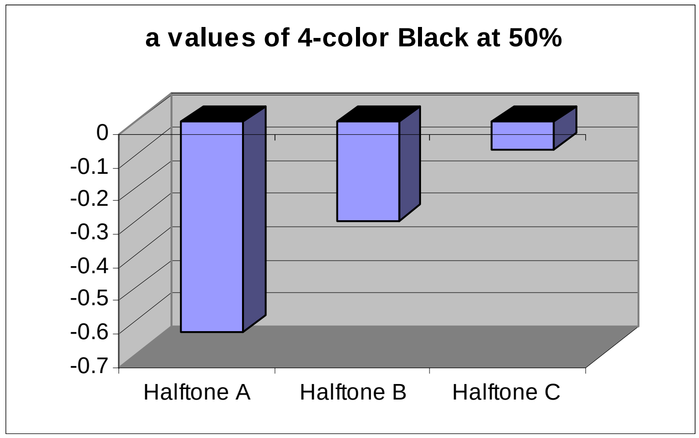


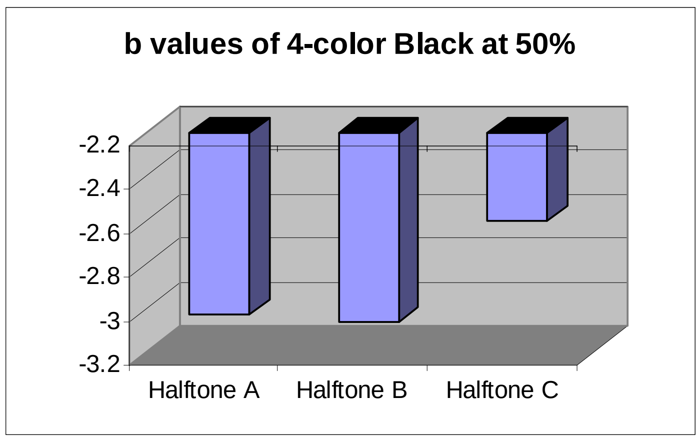


4-color Black at 50%

Average of L values	
Halftone A	72.65
Halftone B	71.959
Halftone C	74.208
Average of a values	
Halftone A	-0.63
Halftone B	-0.296
Halftone C	-0.08
Average of b values	
Halftone A	-3.025
Halftone B	-3.059
Halftone C	-2.595

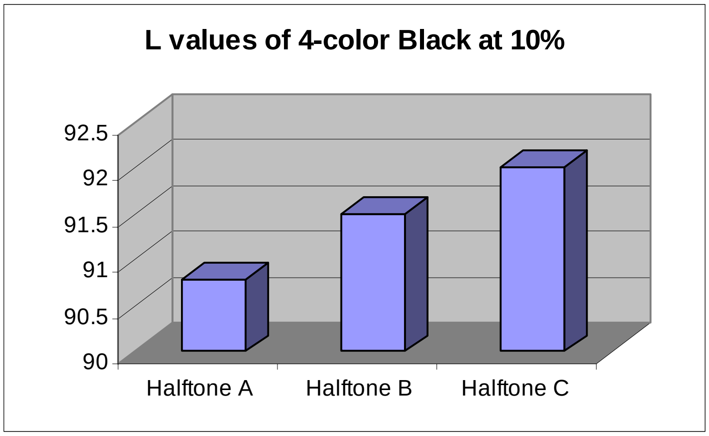


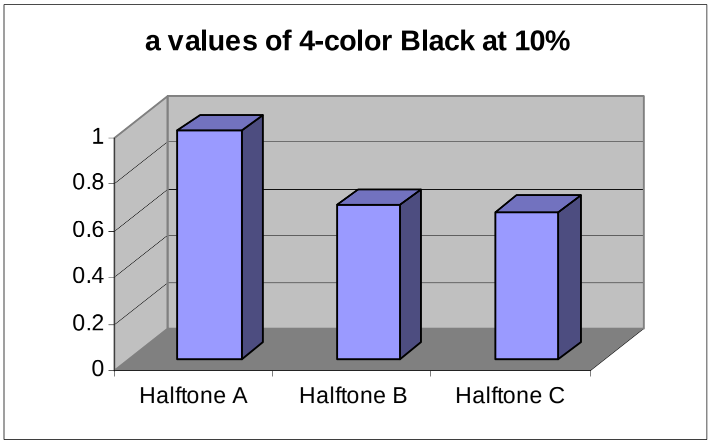


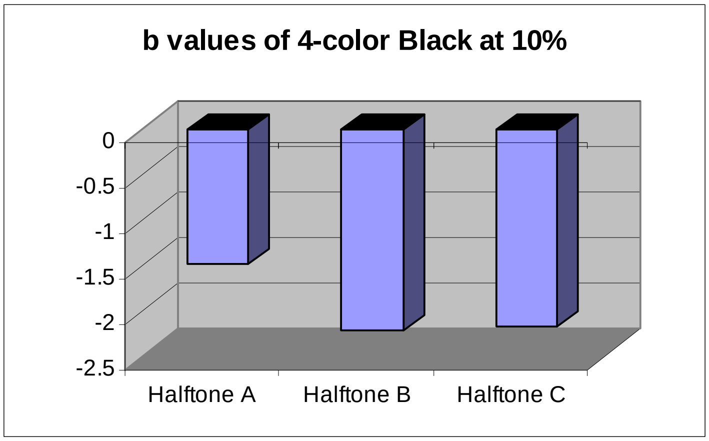


4-color Black at 10%

Average of L values	
Halftone A	90.793
Halftone B	91.5
Halftone C	92.015
Average of a values	
Halftone A	0.974
Halftone B	0.655
Halftone C	0.626
Average of b values	
Halftone A	-1.481
Halftone B	-2.214
Halftone C	-2.172

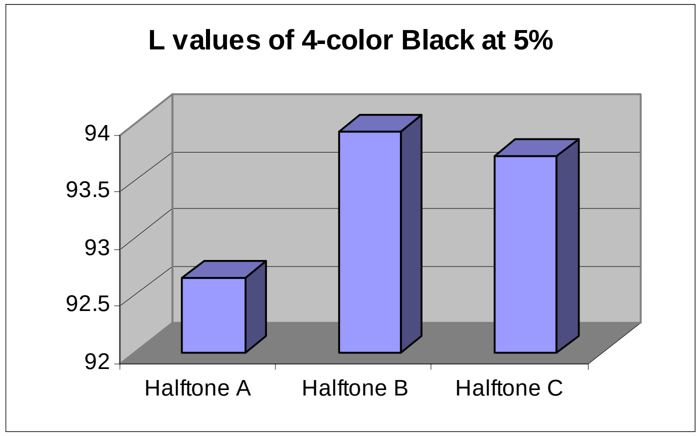


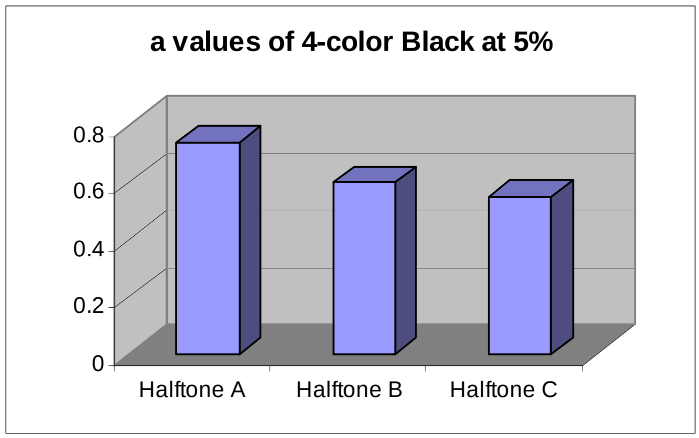


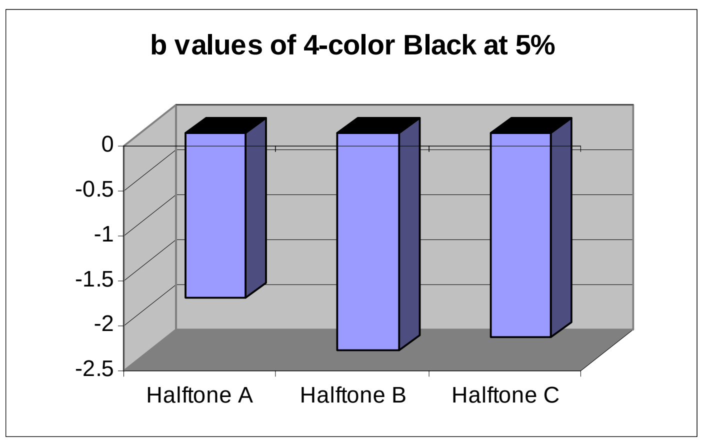


4-color Black at 5%

Average of L values	
Halftone A	92.653
Halftone B	93.921
Halftone C	93.711
Average of a values	
Halftone A	0.736
Halftone B	0.597
Halftone C	0.545
Average of b values	
Halftone A	-1.836
Halftone B	-2.414
Halftone C	-2.267







Appendix L

Delta E Calculations

Shadows

Delta E of the Averages of Red at 97% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	48.7275	**HA-HB**	0.641	0.410881	7.520182	2.742295	Fail to
Halftone B	48.0865	**HB-HC**	-0.055	0.003025	2.543756	1.594916	Fail to
Halftone C	48.0315	**HA-HC**	0.696	0.484416	2.966815	1.722445	Fail to

Average of a values			Sum	Squared
Halftone A	66.951	**HA-HB**	-0.9805	0.96138025
Halftone B	67.9315	**HB-HC**	0.3025	0.09150625
Halftone C	68.234	**HA-HC**	-1.283	1.646089

Average of b values			Sum	Squared
Halftone A	42.1355	**HA-HB**	-2.4795	6.14792025
Halftone B	44.615	**HB-HC**	-1.565	2.449225
Halftone C	43.05	**HA-HC**	-0.9145	0.83631025

Delta E of the Averages of Blue at 97% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	25.781	**HA-HB**	0.706	0.498436	2.633236	1.622725	Fail to
Halftone B	25.075	**HB-HC**	0.712	0.506944	0.634649	0.796649	Fail to
Halftone C	25.787	**HA-HC**	-0.006	3.6E-05	1.261861	1.123326	Fail to

Average of a values			Sum	Squared
Halftone A	34.426	**HA-HB**	1.212	1.468944
Halftone B	33.214	**HB-HC**	0.227	0.051529
Halftone C	33.441	**HA-HC**	0.985	0.970225

Average of b values			Sum	Squared
Halftone A	-38.995	**HA-HB**	0.816	0.665856
Halftone B	-39.811	**HB-HC**	0.276	0.076176
Halftone C	-39.535	**HA-HC**	0.54	0.2916

Delta E of the Averages of Green at 97% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	56.968	**HA-HB**	-1.688	2.849344	8.799093	2.966327	Fail to
Halftone B	58.656	**HB-HC**	0.171	0.029241	1.822675	1.350065	Fail to

Halftone C	58.827	**HA-HC**	-1.859	3.455881	17.65812	4.202157	Reject

Average of a values			Sum	Squared
Halftone A	-56.064	**HA-HB**	-1.79	3.2041
Halftone B	-54.274	**HB-HC**	0.835	0.697225
Halftone C	-53.439	**HA-HC**	-2.625	6.890625

Average of b values			Sum	Squared
Halftone A	21.281	**HA-HB**	-1.657	2.745649
Halftone B	22.938	**HB-HC**	1.047	1.096209
Halftone C	23.985	**HA-HC**	-2.704	7.311616

Midtones

Delta E of the Averages of Red at 50%

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
						At or Below 3	
Halftone A	77.207	**HA-HB**	1.79	3.2041	11.71246	3.422347	Reject
Halftone B	75.417	**HB-HC**	0.655	0.429025	1.91933	1.385399	Fail to
Halftone C	76.072	**HA-HC**	1.135	1.288225	4.176746	2.043709	Fail to

Average of a values			Sum	Squared
Halftone A	18.917	**HA-HB**	-2.771	7.678441
Halftone B	21.688	**HB-HC**	-1.136	1.290496
Halftone C	20.552	**HA-HC**	-1.635	2.673225

Average of b values			Sum	Squared
Halftone A	18.447	**HA-HB**	-0.911	0.829921
Halftone B	19.358	**HB-HC**	-0.447	0.199809
Halftone C	18.911	**HA-HC**	-0.464	0.215296

Delta E of the Averages of Blue at 50%

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
						At or Below 3	
Halftone A	66.426	**HA-HB**	0.256	0.065536	2.348909	1.532615	Fail to
Halftone B	66.17	**HB-HC**	1.262	1.592644	7.058325	2.656751	Fail to
Halftone C	67.432	**HA-HC**	-1.006	1.012036	1.707704	1.306791	Fail to

Average of a values			Sum	Squared
Halftone A	10.744	**HA-HB**	-1.458	2.125764
Halftone B	12.202	**HB-HC**	-2.216	4.910656
Halftone C	9.986	**HA-HC**	0.758	0.574564

Average of b values			Sum	Squared
Halftone A	-20.145	**HA-HB**	0.397	0.157609
Halftone B	-20.542	**HB-HC**	0.745	0.555025
Halftone C	-19.797	**HA-HC**	-0.348	0.121104

Delta E of the Averages of Green at 50%

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
						At or Below 3	
Halftone A	81.425	**HA-HB**	1.297	1.682209	4.925417	2.219328	Fail to
Halftone B	80.128	**HB-HC**	0.532	0.283024	1.043661	1.021597	Fail to
Halftone C	80.66	**HA-HC**	0.765	0.585225	1.44905	1.203765	Fail to

Average of a values			Sum	Squared
Halftone A	-15.999	**HA-HB**	1.798	3.232804

Halftone B	-17.797	**HB-HC**	0.869	0.755161
Halftone C	-16.928	**HA-HC**	0.929	0.863041

Average of b values			Sum	Squared
Halftone A	10.553	**HA-HB**	-0.102	0.010404
Halftone B	10.655	**HB-HC**	-0.074	0.005476
Halftone C	10.581	**HA-HC**	-0.028	0.000784

Highlights

Delta E of the Averages of Red at 10% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	91.931	**HA-HB**	-0.723	0.522729	2.208883	1.486231	Fail to
Halftone B	92.654	**HB-HC**	-0.317	0.100489	0.520753	0.721632	Fail to
Halftone C	92.337	**HA-HC**	-0.406	0.164836	0.587822	0.766696	Fail to

Average of a values			Sum	Squared
Halftone A	3.349	**HA-HB**	0.645	0.416025
Halftone B	2.704	**HB-HC**	0.33	0.1089
Halftone C	3.034	**HA-HC**	0.315	0.099225

Average of b values			Sum	Squared
Halftone A	1.244	**HA-HB**	1.127	1.270129
Halftone B	0.117	**HB-HC**	0.558	0.311364
Halftone C	0.675	**HA-HC**	0.569	0.323761

Delta E of the Averages of Blue at 10% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	89.366	**HA-HB**	-1.78	3.1684	4.91018	2.215893	Fail to
Halftone B	91.146	**HB-HC**	0.169	0.028561	0.039586	0.198962	Fail to
Halftone C	91.315	**HA-HC**	-1.949	3.798601	5.772662	2.402636	Fail to

Average of a values			Sum	Squared
Halftone A	2.481	**HA-HB**	0.366	0.133956
Halftone B	2.115	**HB-HC**	-0.084	0.007056
Halftone C	2.031	**HA-HC**	0.45	0.2025

Average of b values			Sum	Squared
Halftone A	-6.84	**HA-HB**	-1.268	1.607824
Halftone B	-5.572	**HB-HC**	0.063	0.003969
Halftone C	-5.509	**HA-HC**	-1.331	1.771561

Delta E of the Averages of Green at 10%

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	92.859	**HA-HB**	-0.515	0.265225	0.57785	0.760164	Fail to
Halftone B	93.374	**HB-HC**	-0.216	0.046656	0.083408	0.288804	Fail to
Halftone C	93.158	**HA-HC**	-0.299	0.089401	0.231458	0.481101	Fail to

Average of a values			Sum	Squared
Halftone A	-2.391	**HA-HB**	-0.44	0.1936
Halftone B	-1.951	**HB-HC**	-0.176	0.030976
Halftone C	-2.127	**HA-HC**	-0.264	0.069696

Average of b values			Sum	Squared
Halftone A	0.023	**HA-HB**	0.345	0.119025
Halftone B	-0.322	**HB-HC**	0.076	0.005776
Halftone C	-0.246	**HA-HC**	0.269	0.072361

Delta E of the Averages of Red at 5% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	92.814	**HA-HB**	-0.851	0.724201	3.275837	1.809927	Fail to
Halftone B	93.665	**HB-HC**	0.106	0.011236	0.028661	0.169296	Fail to
Halftone C	93.771	**HA-HC**	-0.957	0.915849	3.118454	1.765914	Fail to

Average of a values			Sum	Squared
Halftone A	2.402	**HA-HB**	0.78	0.6084
Halftone B	1.622	**HB-HC**	-0.001	1E-06
Halftone C	1.621	**HA-HC**	0.781	0.609961

Average of b values			Sum	Squared
Halftone A	0.175	**HA-HB**	1.394	1.943236
Halftone B	-1.219	**HB-HC**	0.132	0.017424
Halftone C	-1.087	**HA-HC**	1.262	1.592644

Delta E of the Averages of Blue at 5% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	91.759	**HA-HB**	-1.357	1.841449	3.553854	1.885167	Fail to
Halftone B	93.116	**HB-HC**	0.158	0.024964	0.033293	0.182464	Fail to
Halftone C	93.274	**HA-HC**	-1.515	2.295225	3.895571	1.97372	Fail to

Average of a values			Sum	Squared
Halftone A	1.992	**HA-HB**	0.553	0.305809
Halftone B	1.439	**HB-HC**	-0.052	0.002704
Halftone C	1.387	**HA-HC**	0.605	0.366025

Average of b values			Sum	Squared
Halftone A	-5.119	**HA-HB**	-1.186	1.406596
Halftone B	-3.933	**HB-HC**	-0.075	0.005625
Halftone C	-4.008	**HA-HC**	-1.111	1.234321

Delta E of the Averages of Green at 5% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	93.499	**HA-HB**	-0.934	0.872356	3.614966	1.901306	Fail to
Halftone B	94.433	**HB-HC**	-0.091	0.008281	0.044934	0.211976	Fail to
Halftone C	94.342	**HA-HC**	-0.843	0.710649	2.894158	1.701223	Fail to

Average of a values			Sum	Squared
Halftone A	-1.463	**HA-HB**	-1.163	1.352569
Halftone B	-0.3	**HB-HC**	-0.173	0.029929
Halftone C	-0.473	**HA-HC**	-0.99	0.9801

Average of b values			Sum	Squared
Halftone A	-0.658	**HA-HB**	1.179	1.390041
Halftone B	-1.837	**HB-HC**	0.082	0.006724
Halftone C	-1.755	**HA-HC**	1.097	1.203409

3-color and 4-color Black

Delta E of the Averages of 4-color Black at 97% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	25.245	**HA-HB**	2.672	7.139584	9.961818	3.156235	Reject
Halftone B	22.573	**HB-HC**	5.336	28.472896	31.56521	5.618293	Reject
Halftone C	27.909	**HA-HC**	-2.664	7.096896	16.0755	4.009427	Reject

Average of a values			Sum	Squared
Halftone A	2.641	**HA-HB**	-0.655	0.429025
Halftone B	3.296	**HB-HC**	-1.029	1.058841
Halftone C	2.267	**HA-HC**	0.374	0.139876

Average of b values			Sum	Squared
Halftone A	-0.912	**HA-HB**	-1.547	2.393209
Halftone B	0.635	**HB-HC**	1.426	2.033476
Halftone C	2.061	**HA-HC**	-2.973	8.838729

Delta E of the Averages of 4-color Black at 50%

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	65.39925	**HA-HB**	1.831	3.352561	3.387939	1.840635	Fail to
Halftone B	63.56825	**HB-HC**	1.7085	2.91897225	3.243612	1.801003	Fail to
Halftone C	65.27675	**HA-HC**	0.1225	0.01500625	0.352925	0.594075	Fail to

Average of a values			Sum	Squared
Halftone A	-2.2335	**HA-HB**	-0.18725	0.03506256
Halftone B	-2.04625	**HB-HC**	-0.005	2.5E-05
Halftone C	-2.05125	**HA-HC**	-0.18225	0.03321506

Average of b values			Sum	Squared
Halftone A	-1.25425	**HA-HB**	0.01775	0.00031506
Halftone B	-1.272	**HB-HC**	0.56975	0.32461506
Halftone C	-0.70225	**HA-HC**	-0.552	0.304704

Delta E of the Averages of 4-color Black at 10% At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	90.793	**HA-HB**	-0.707	0.499849	1.138899	1.067192	Fail to
Halftone B	91.5	**HB-HC**	0.515	0.265225	0.26783	0.517523	Fail to
Halftone C	92.015	**HA-HC**	-1.222	1.493284	2.091869	1.446329	Fail to

Average of a values			Sum	Squared
Halftone A	0.974	**HA-HB**	0.319	0.101761
Halftone B	0.655	**HB-HC**	-0.029	0.000841
Halftone C	0.626	**HA-HC**	0.348	0.121104

Average of b values			Sum	Squared
Halftone A	-1.481	**HA-HB**	0.733	0.537289
Halftone B	-2.214	**HB-HC**	0.042	0.001764
Halftone C	-2.172	**HA-HC**	0.691	0.477481

Delta E of the Averages of 4-color Black at 5% At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	92.653	**HA-HB**	-1.268	1.607824	1.961229	1.400439	Fail to
Halftone B	93.921	**HB-HC**	-0.21	0.0441	0.068413	0.261559	Fail to
Halftone C	93.711	**HA-HC**	-1.058	1.119364	1.341606	1.158277	Fail to

Average of a values			Sum	Squared
Halftone A	0.736	**HA-HB**	0.139	0.019321
Halftone B	0.597	**HB-HC**	-0.052	0.002704
Halftone C	0.545	**HA-HC**	0.191	0.036481

Average of b values			Sum	Squared
Halftone A	-1.836	**HA-HB**	0.578	0.334084
Halftone B	-2.414	**HB-HC**	0.147	0.021609
Halftone C	-2.267	**HA-HC**	0.431	0.185761

Delta E of the Averages of 3-color Black at 97% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	37.302	**HA-HB**	1.512	2.286144	10.69672	3.270585	Reject
Halftone B	35.79	**HB-HC**	1.371	1.879641	8.345581	2.888872	Fail to
Halftone C	37.161	**HA-HC**	0.141	0.019881	7.927721	2.815621	Fail to

Average of a values			Sum	Squared
Halftone A	10.444	**HA-HB**	-1.966	3.865156
Halftone B	12.41	**HB-HC**	-2.462	6.061444
Halftone C	9.948	**HA-HC**	0.496	0.246016

Average of b values			Sum	Squared
Halftone A	1.243	**HA-HB**	-2.132	4.545424
Halftone B	3.375	**HB-HC**	0.636	0.404496
Halftone C	4.011	**HA-HC**	-2.768	7.661824

Delta E of the Averages of 3-color Black at 50% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	70.33	**HA-HB**	1.963	3.853369	4.61179	2.147508	Fail to
Halftone B	68.367	**HB-HC**	2.571	6.610041	6.664131	2.581498	Fail to
Halftone C	70.938	**HA-HC**	-0.608	0.369664	0.798793	0.893752	Fail to

Average of a values			Sum	Squared
Halftone A	2.528	**HA-HB**	-0.786	0.617796
Halftone B	3.314	**HB-HC**	-0.231	0.053361
Halftone C	3.083	**HA-HC**	-0.555	0.308025

Average of b values			Sum	Squared
Halftone A	1.713	**HA-HB**	-0.375	0.140625
Halftone B	2.088	**HB-HC**	-0.027	0.000729
Halftone C	2.061	**HA-HC**	-0.348	0.121104

Delta E of the Averages of 3-color Black at 10% — At or Below 3

Average of L values			Sum	Squared	Sum Sq	Delta E	Null
Halftone A	90.678	**HA-HB**	-0.655	0.429025	0.714654	0.845372	Fail to
Halftone B	91.333	**HB-HC**	0.575	0.330625	0.338025	0.581399	Fail to
Halftone C	91.908	**HA-HC**	-1.23	1.5129	1.890149	1.374827	Fail to

Average of a values			Sum	Squared
Halftone A	1.085	**HA-HB**	0.11	0.0121
Halftone B	0.975	**HB-HC**	-0.05	0.0025
Halftone C	0.925	**HA-HC**	0.16	0.0256

Average of b values			Sum	Squared
Halftone A	-1.194	**HA-HB**	0.523	0.273529
Halftone B	-1.717	**HB-HC**	-0.07	0.0049
Halftone C	-1.787	**HA-HC**	0.593	0.351649

Delta E of the Averages of 3-color Black at 5%

Average of L values			Sum	Squared	Sum Sq	At or Below 3 Delta E	Null
Halftone A	92.99	**HA-HB**	-1.153	1.329409	1.712611	1.308668	Fail to
Halftone B	94.143	**HB-HC**	-0.124	0.015376	0.017016	0.130445	Fail to
Halftone C	94.019	**HA-HC**	-1.029	1.058841	1.424435	1.193497	Fail to

Average of a values			Sum	Squared
Halftone A	0.975	**HA-HB**	0.111	0.012321
Halftone B	0.864	**HB-HC**	-0.034	0.001156
Halftone C	0.83	**HA-HC**	0.145	0.021025

Average of b values			Sum	Squared
Halftone A	-1.799	**HA-HB**	0.609	0.370881
Halftone B	-2.408	**HB-HC**	0.022	0.000484
Halftone C	-2.386	**HA-HC**	0.587	0.344569

Appendix M

Charts of the Selections Made by the Participants During the Evaluation of the Halftones

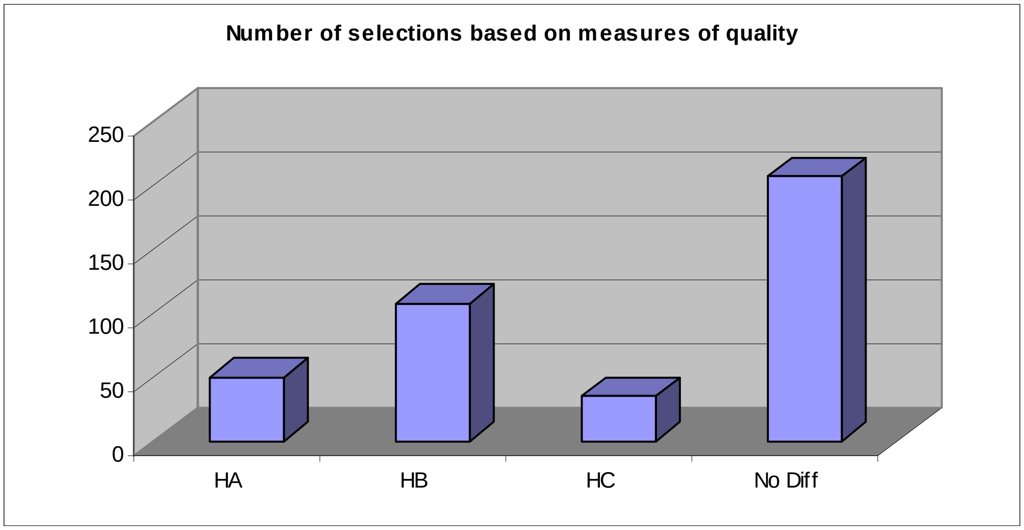
Percentage of Total Choices

Halftone A			
Non printers		Printers	
50		15	
44		39	
106		63	
71		59	
60		73	
Choices	Possible	Choices	Possible
331	2000	249	1225
Percentage	16%	Percentage	20%
Halftone B			
Non printers		Printers	
108		71	
164		127	
62		54	
59		46	
100		53	
Choices	Possible	Choices	Possible
493	2000	351	1225
Percentage	25%	Percentage	29%
Halftone C			
Non printers		Printers	
35		71	
60		35	
83		51	
73		36	
46		43	
Choices	Possible	Choices	Possible
297	2000	236	1225
Percentage	15%	Percentage	19%
No Difference			
Non printers		Printers	
207		88	
132		44	
149		77	
197		104	
194		76	
Choices	Possible	Choices	Possible

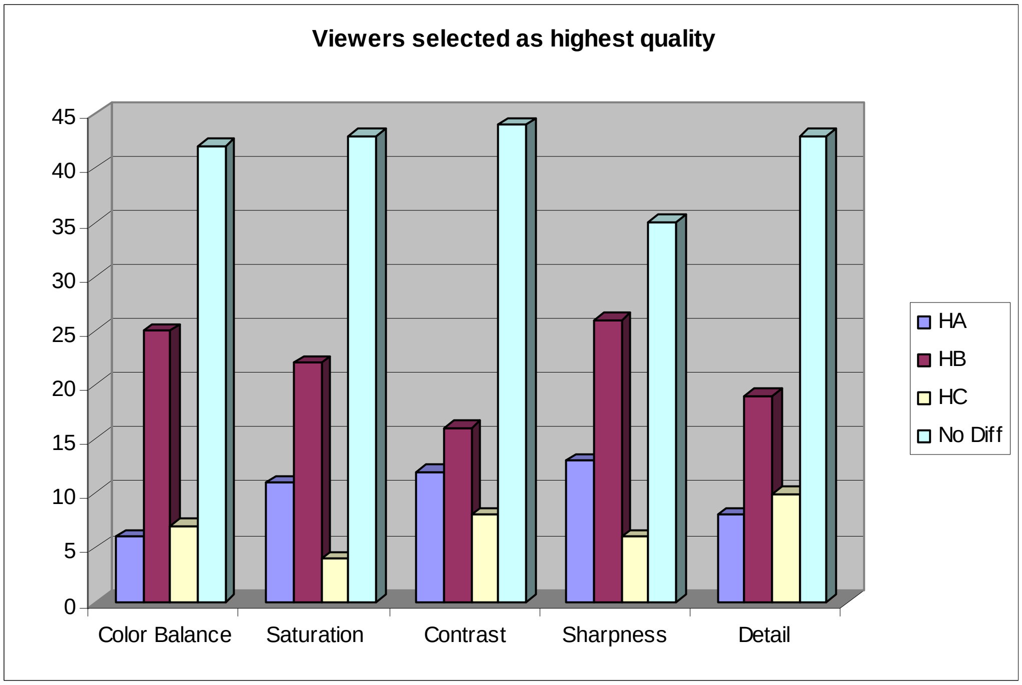
879	2000	389	1225
Percentage	44%	Percentage	32%

Non Printers evaluating the Iguana

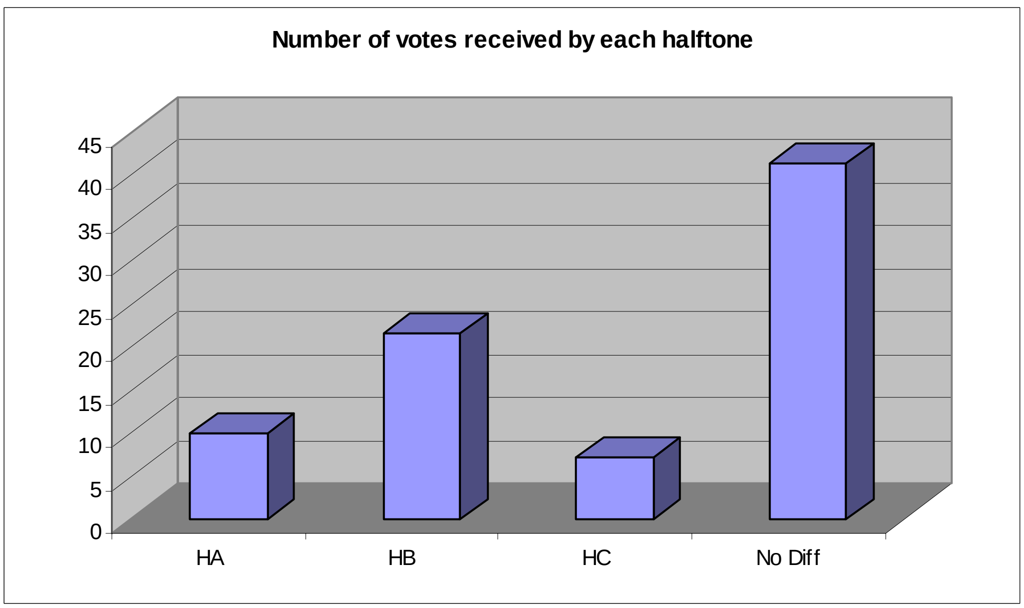
HA	HB	HC	No Diff	Total Number of Selections		
50	108	35	207	400		



	Color Balance	Saturation	Contrast	Sharpness	Detail
HA	6	11	12	13	8
HB	25	22	16	26	19
HC	7	4	8	6	10
No Diff	42	43	44	35	43

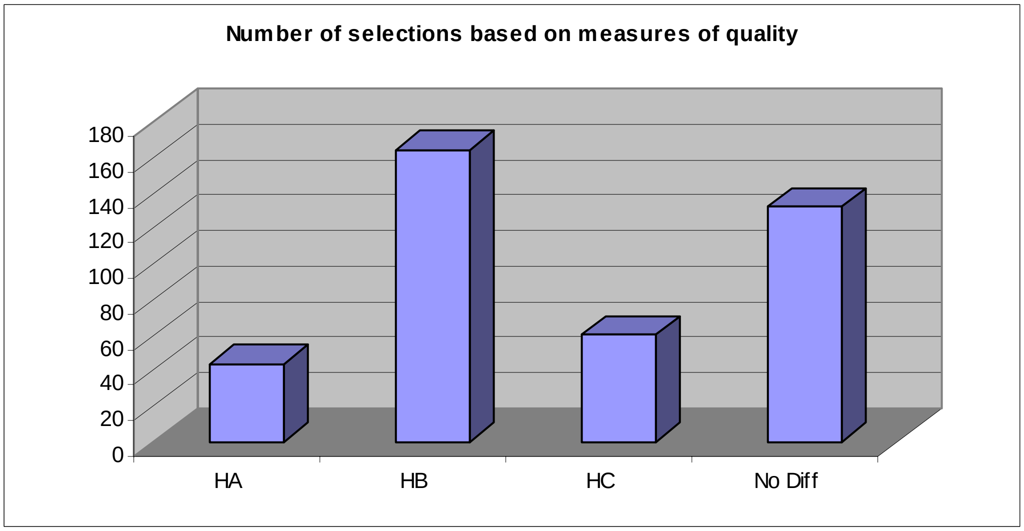


HA	HB	HC	No Diff
10	21.6	7	41.4

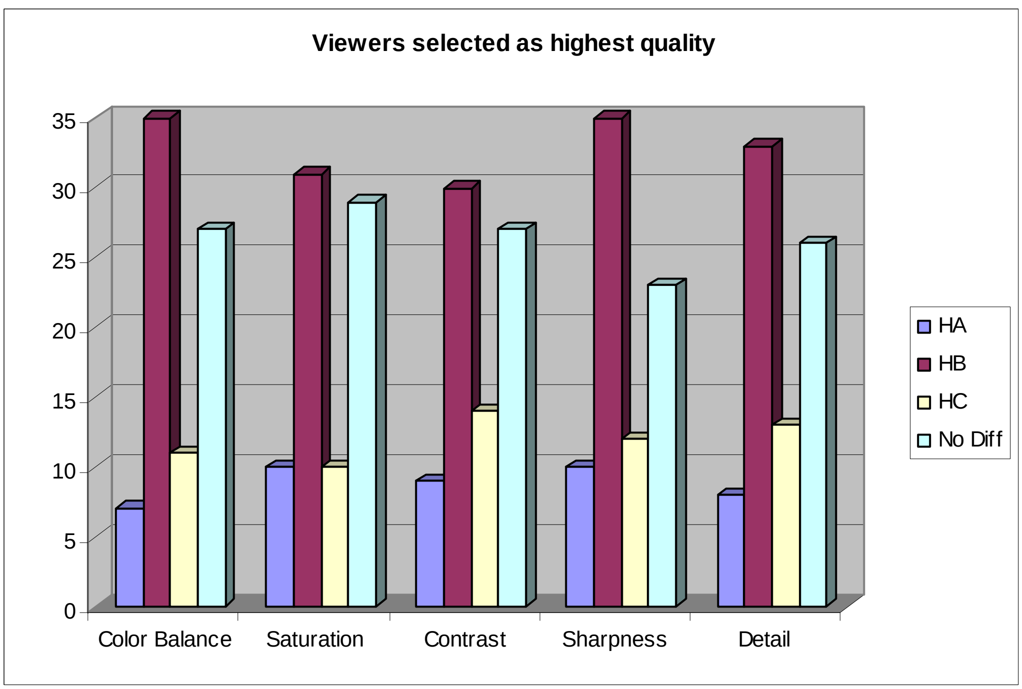


Non-Printers evaluating the Cougar

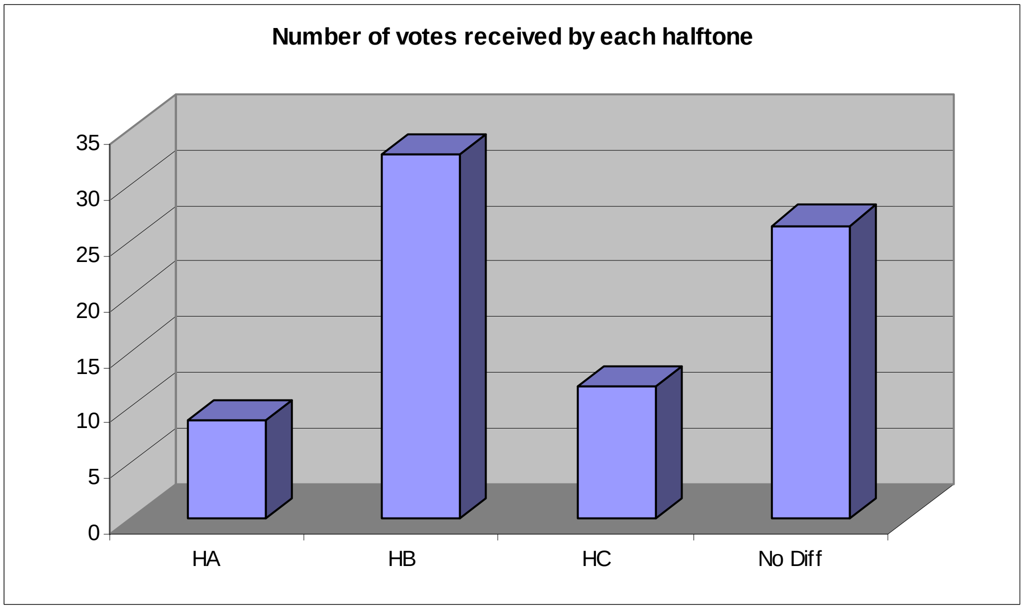
HA	HB	HC	No Diff	Total Number of Selections		
44	164	60	132	400		



	Color Balance	Saturation	Contrast	Sharpness	Detail
HA	7	10	9	10	8
HB	35	31	30	35	33
HC	11	10	14	12	13
No Diff	27	29	27	23	26

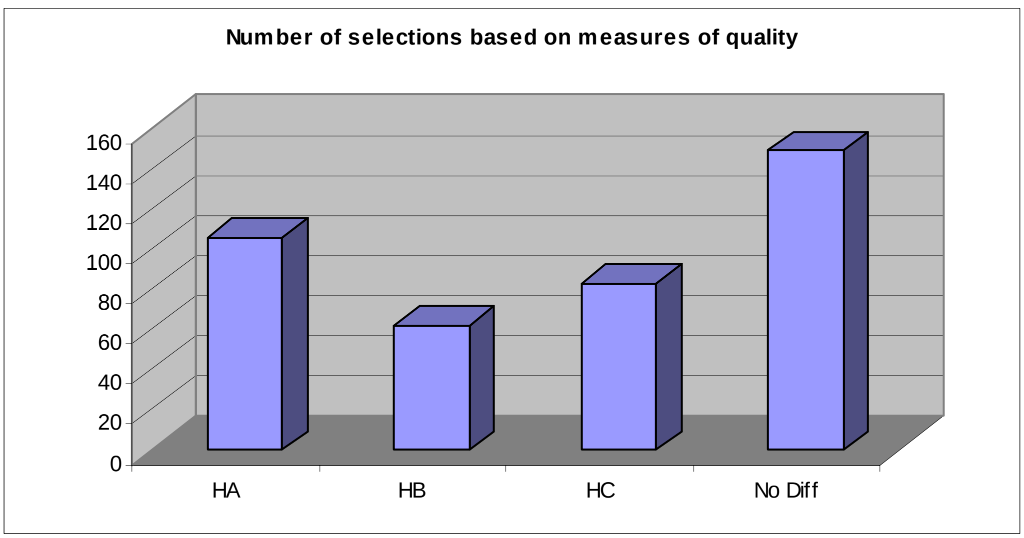


HA	HB	HC	No Diff
8.8	32.8	12	26.4

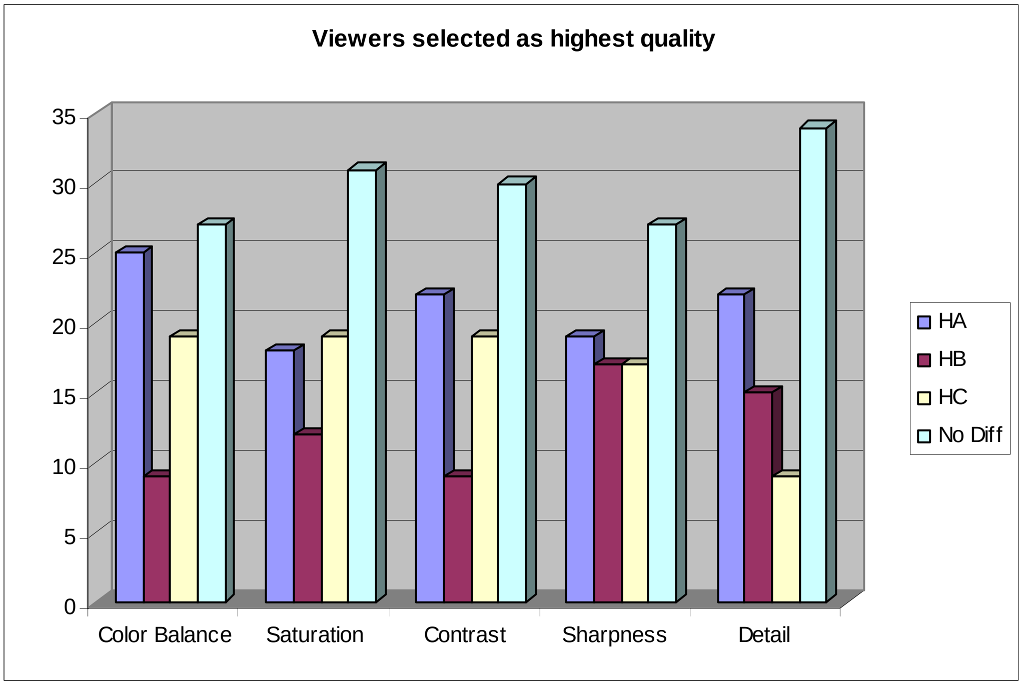


Non-Printers evaluating the Leaf

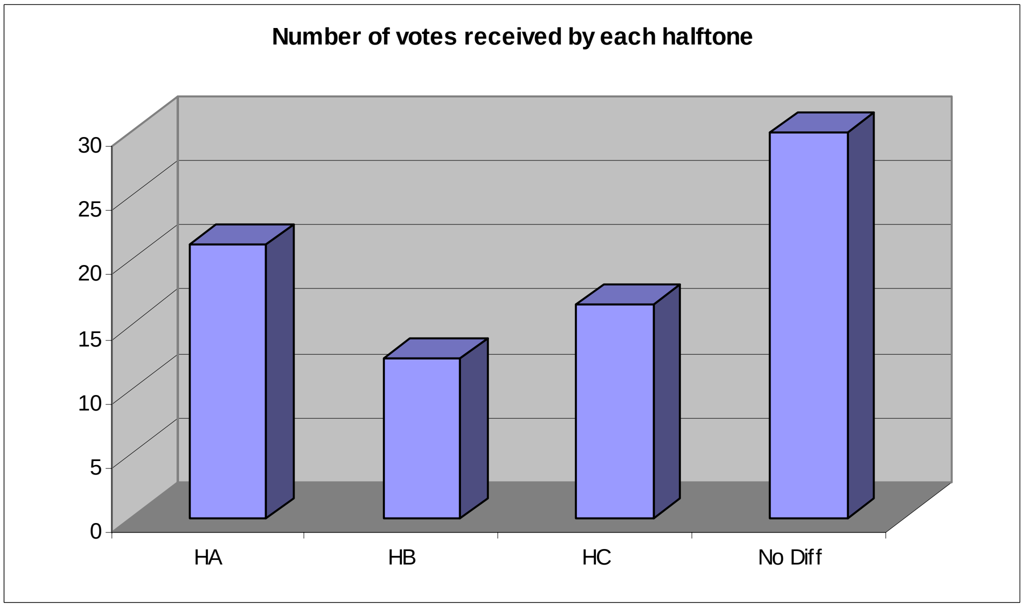
HA	HB	HC	No Diff	Total Number of Selections		
106	62	83	149	400		



	Color Balance	Saturation	Contrast	Sharpness	Detail
HA	25	18	22	19	22
HB	9	12	9	17	15
HC	19	19	19	17	9
No Diff	27	31	30	27	34

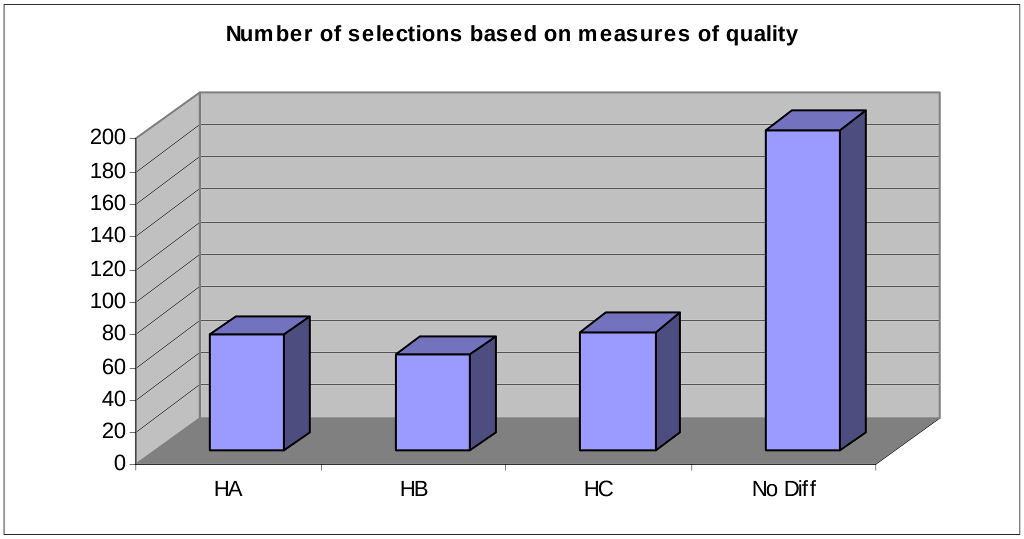


HA	HB	HC	No Diff
21.2	12.4	16.6	29.8

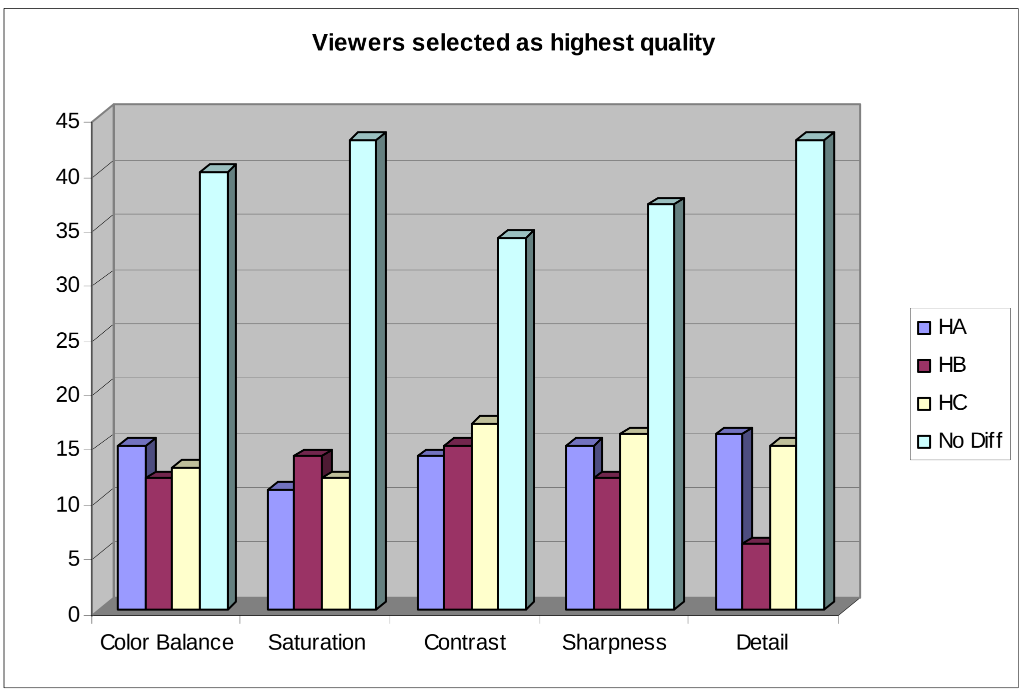


<u>Non-Printers evaluating the Spools</u>

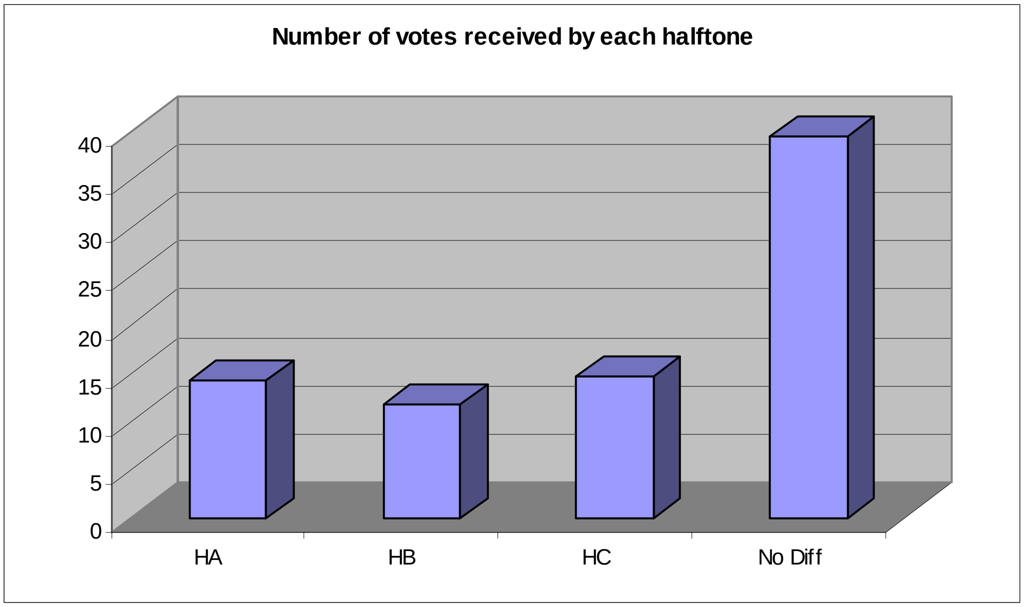
HA	HB	HC	No Diff	Total Number of Selections		
71	59	73	197	400		



	Color Balance	Saturation	Contrast	Sharpness	Detail
HA	15	11	14	15	16
HB	12	14	15	12	6
HC	13	12	17	16	15
No Diff	40	43	34	37	43

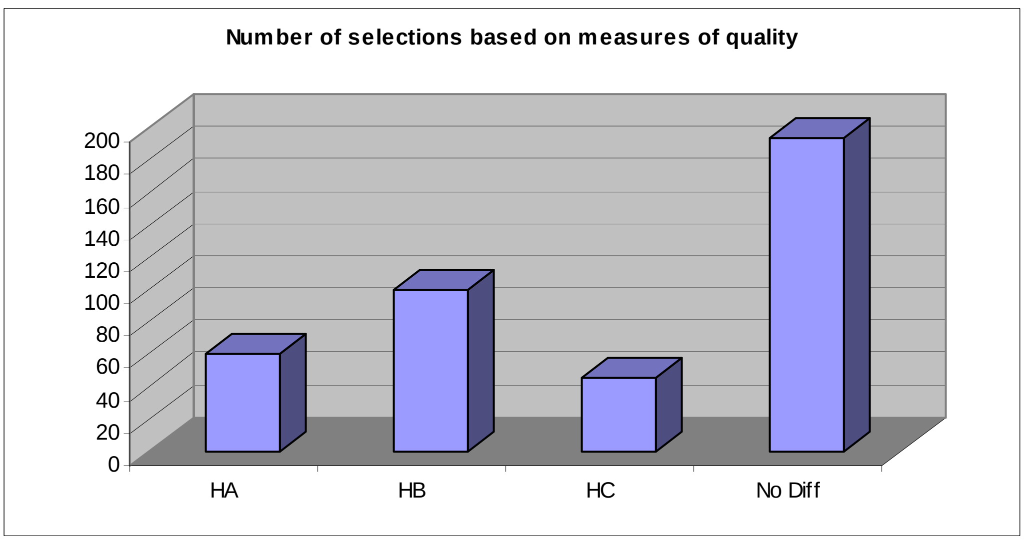


HA	HB	HC	No Diff
14.2	11.8	14.6	39.4

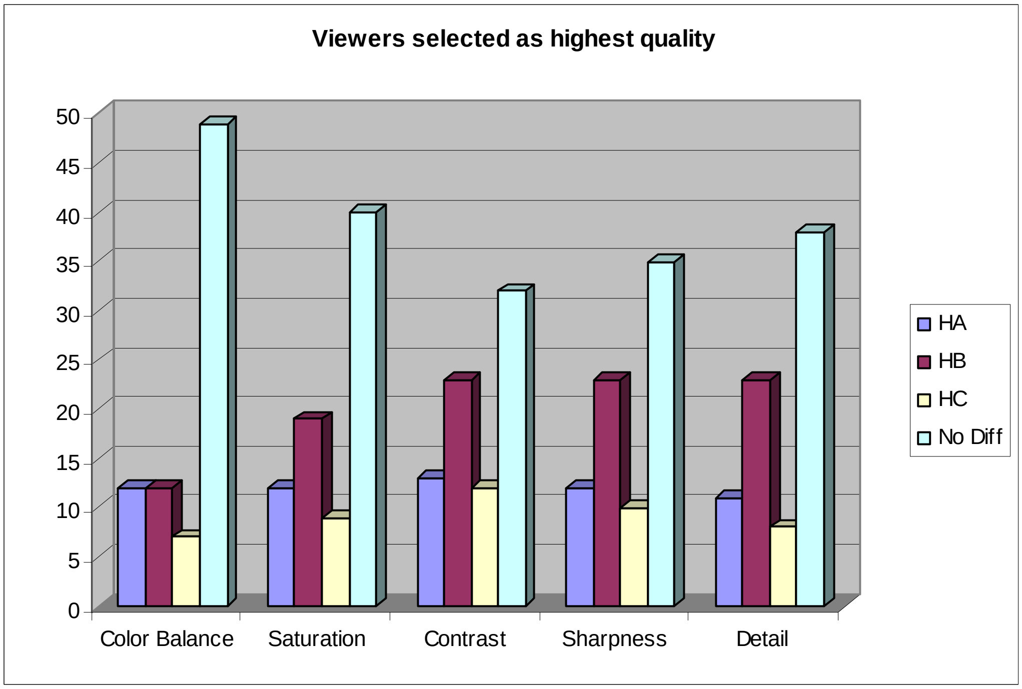


Non-Printer evaluating the Hallway

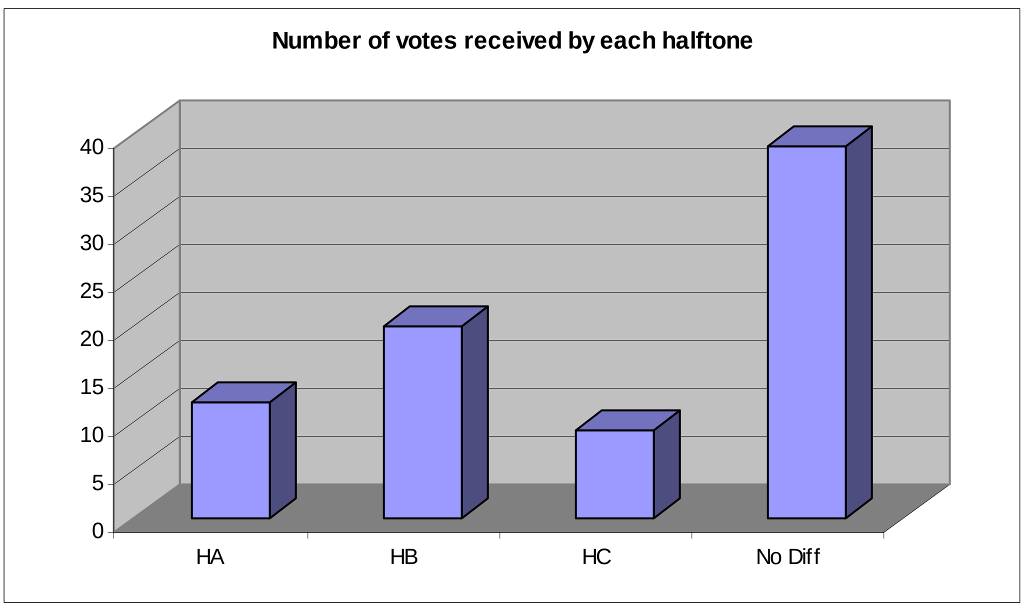
HA	HB	HC	No Diff	Total Number of Selections		
60	100	46	194	400		



	Color Balance	Saturation	Contrast	Sharpness	Detail
HA	12	12	13	12	11
HB	12	19	23	23	23
HC	7	9	12	10	8
No Diff	49	40	32	35	38

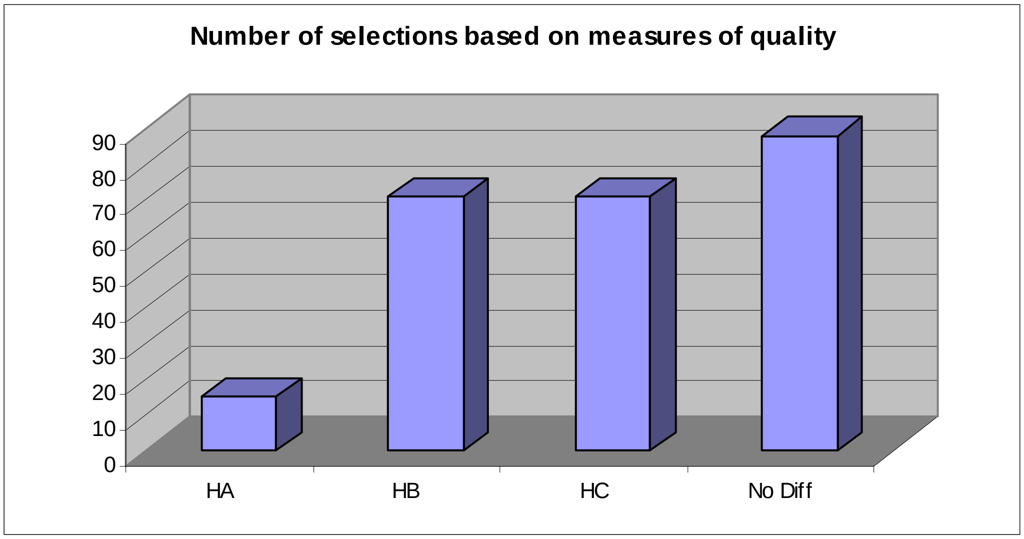


HA	HB	HC	No Diff
12	20	9.2	38.8

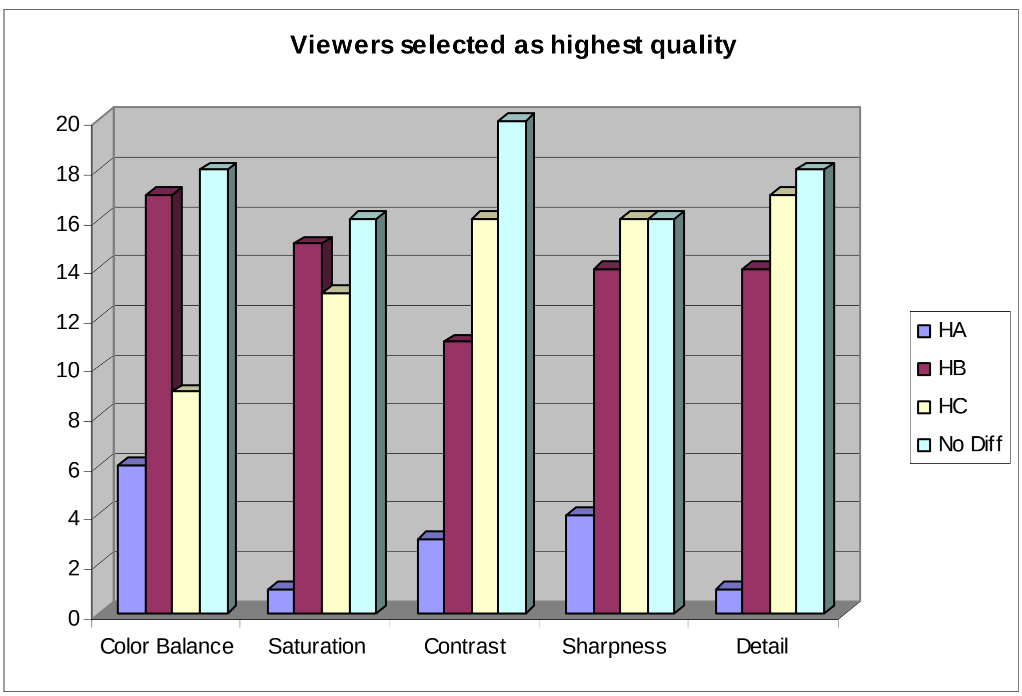


Printers evaluating the Iguana

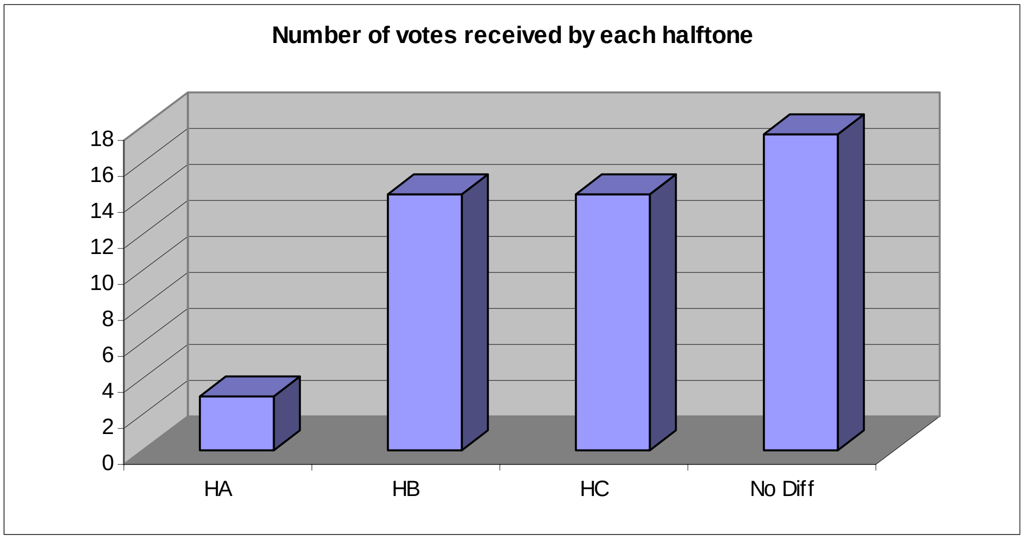
HA	HB	HC	No Diff	Total Number of Selections		
15	71	71	88	245		



	Color Balance	Saturation	Contrast	Sharpness	Detail
HA	6	1	3	4	1
HB	17	15	11	14	14
HC	9	13	16	16	17
No Diff	18	16	20	16	18

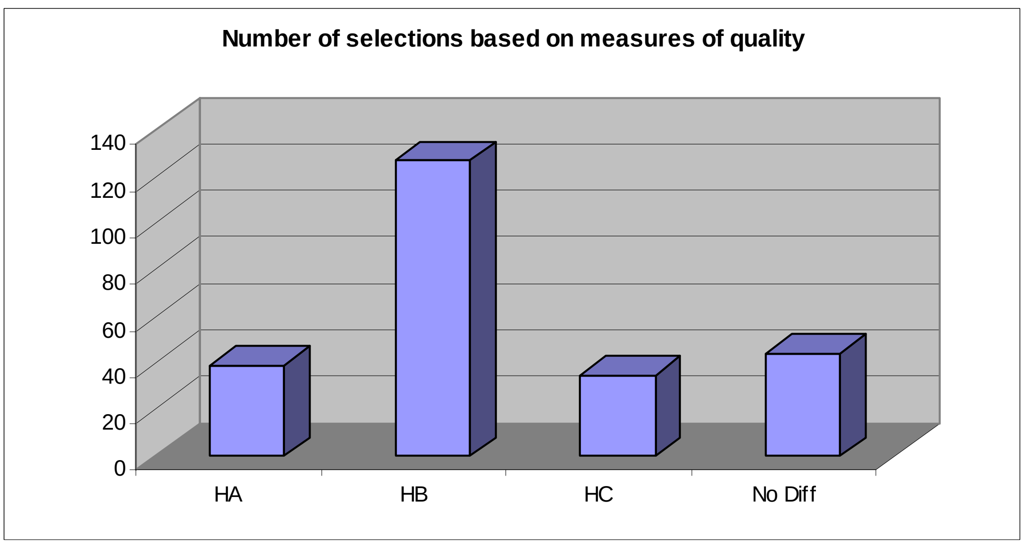


HA	HB	HC	No Diff
3	14.2	14.2	17.6

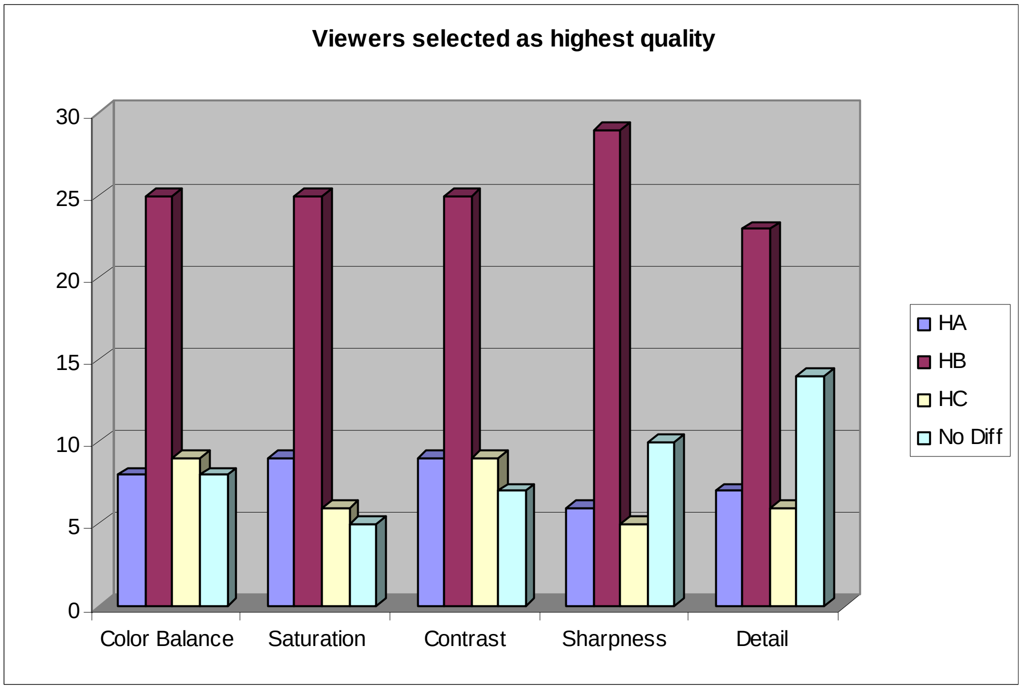


<u>Printers evaluating the Cougar</u>

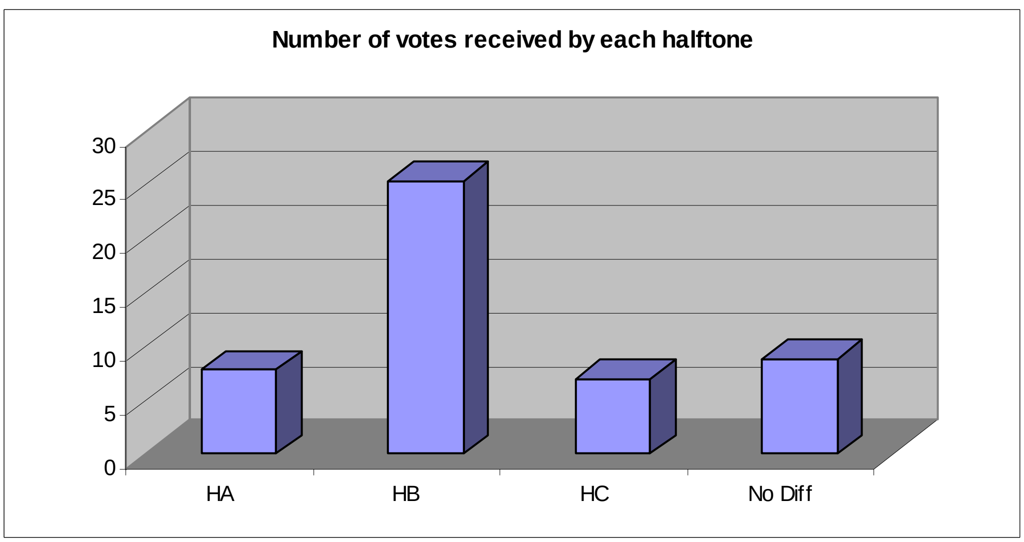
HA	HB	HC	No Diff	Total Number of Selections		
39	127	35	44	245		



	Color Balance	Saturation	Contrast	Sharpness	Detail
HA	8	9	9	6	7
HB	25	25	25	29	23
HC	9	6	9	5	6
No Diff	8	5	7	10	14

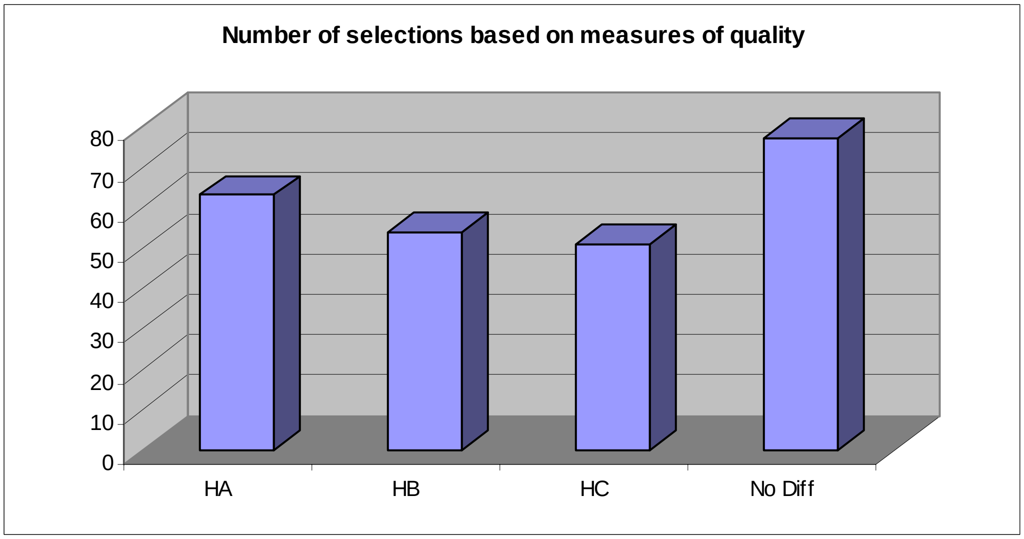


HA	HB	HC	No Diff
7.8	25.4	7	8.8

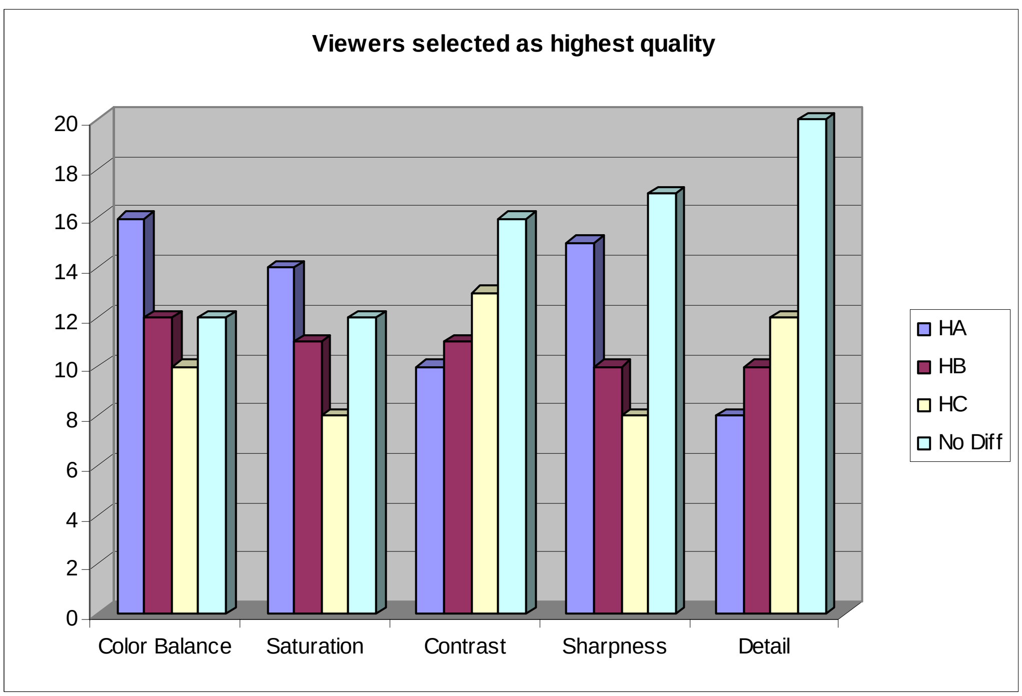


Printers evaluating the Leaf

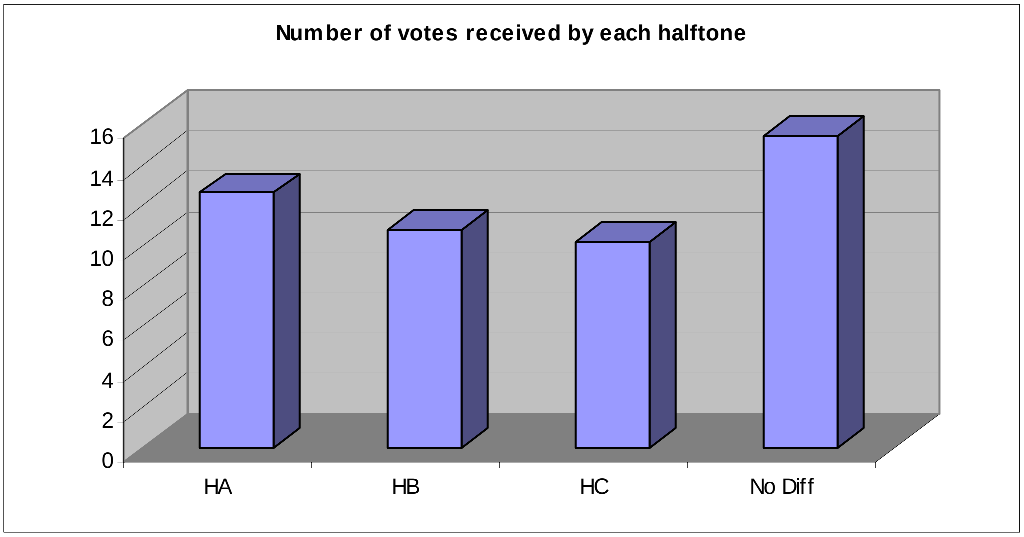
HA	HB	HC	No Diff	Total Number of Selections		
63	54	51	77	245		



	Color Balance	Saturation	Contrast	Sharpness	Detail
HA	16	14	10	15	8
HB	12	11	11	10	10
HC	10	8	13	8	12
No Diff	12	12	16	17	20

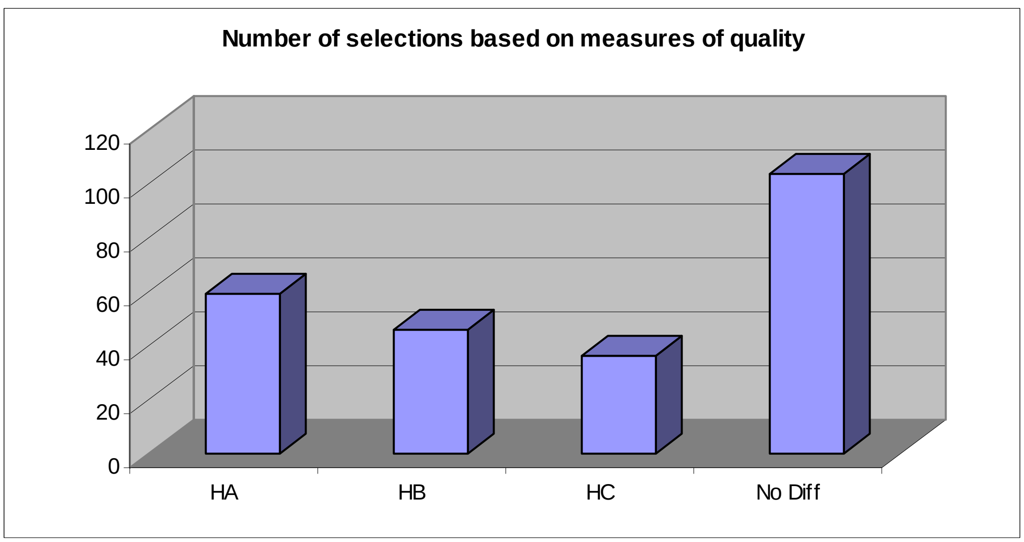


HA	HB	HC	No Diff
12.6	10.8	10.2	15.4

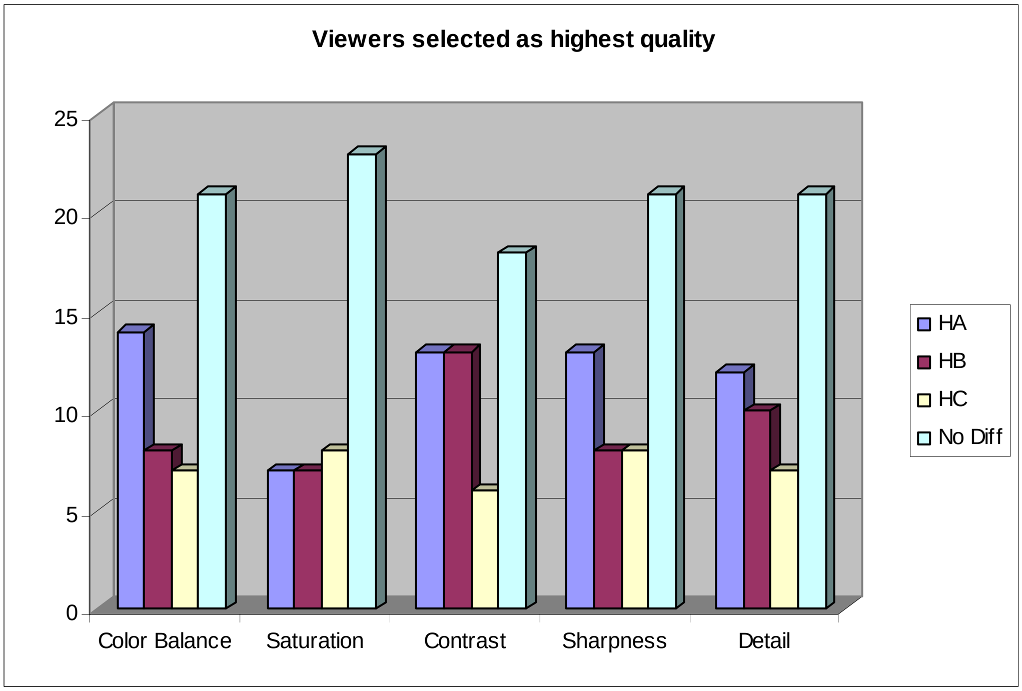


Printers evaluating the Spools

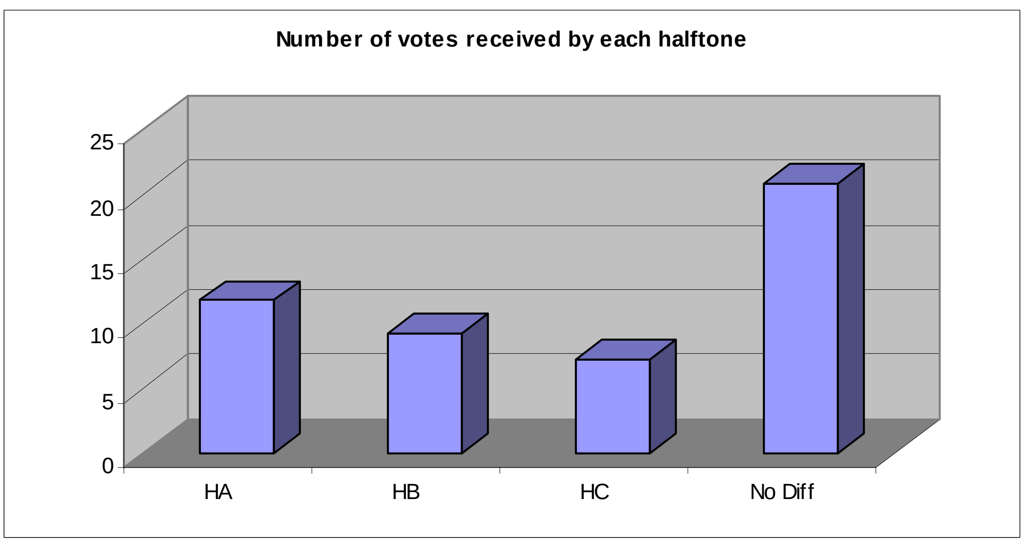
HA	HB	HC	No Diff	Total Number of Selections		
59	46	36	104	245		



	Color Balance	Saturation	Contrast	Sharpness	Detail
HA	14	7	13	13	12
HB	8	7	13	8	10
HC	7	8	6	8	7
No Diff	21	23	18	21	21

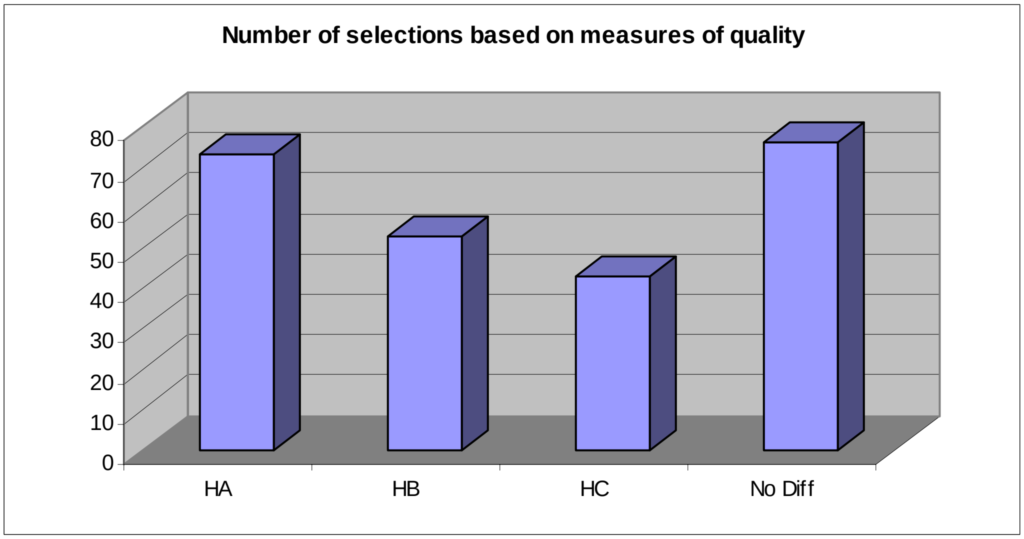


HA	HB	HC	No Diff
11.8	9.2	7.2	20.8

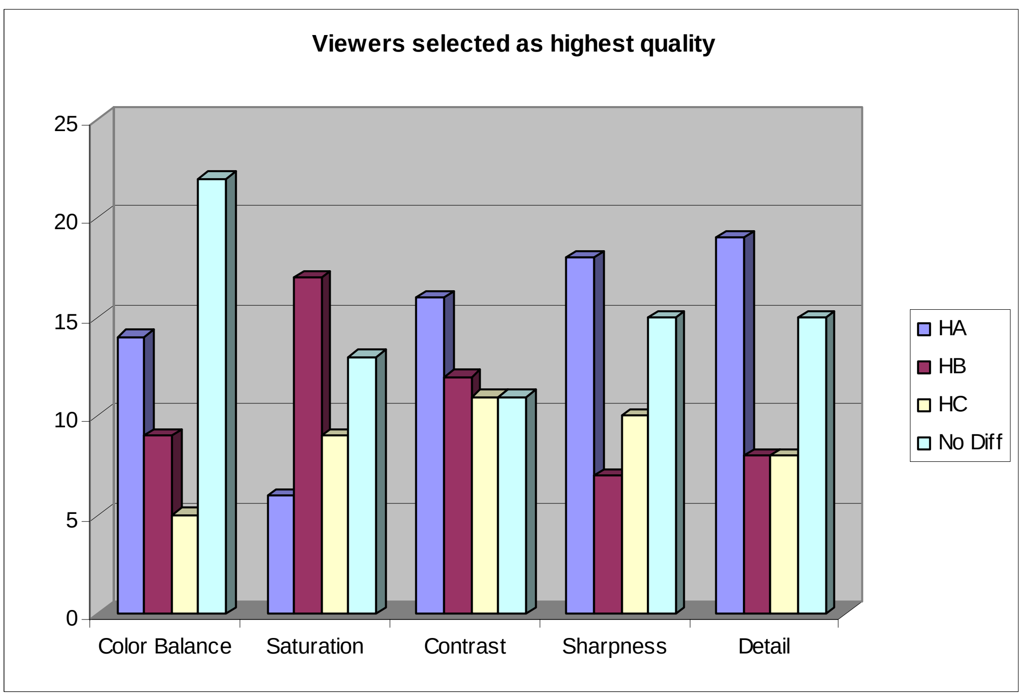


Printers evaluating the Hallway

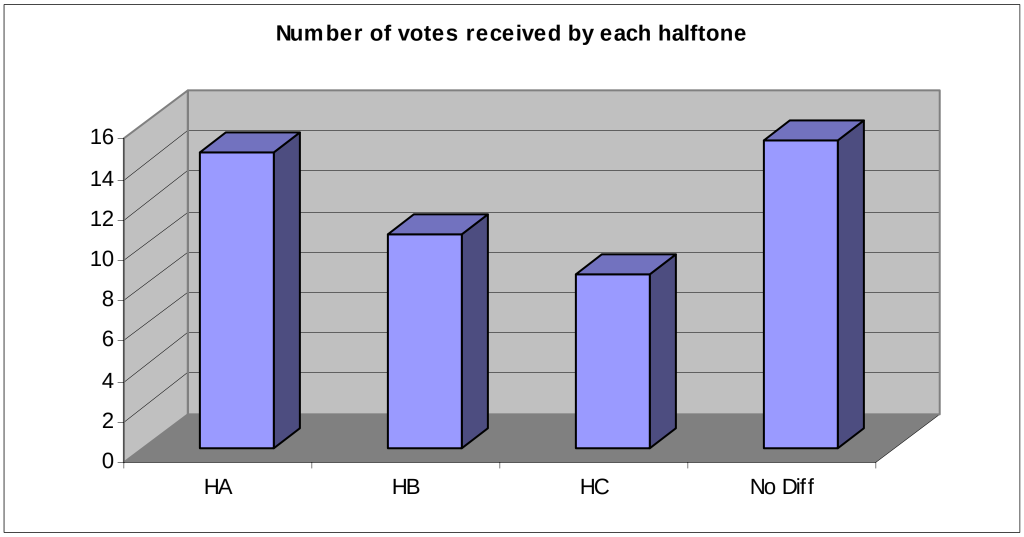
HA	HB	HC	No Diff	Total Number of Selections		
73	53	43	76	245		



	Color Balance	Saturation	Contrast	Sharpness	Detail
HA	14	6	16	18	19
HB	9	17	12	7	8
HC	5	9	11	10	8
No Diff	22	13	11	15	15



HA	HB	HC	No Diff
14.6	10.6	8.6	15.2


Number of votes received by each halftone
16
14
12
10
8
6
4
2
0
HA
HB
HC
No Diff

Appendix N

ANOVAs of the Selections During the Evaluation of the Halftones

Total # of Choices made	HA	HB	HC	Marginal 1	No Diff
Observed	580	844	533	1957	1268
Expected	652.333	652.333	652.333	1957	
Marginal 2	1232.333	1496.333	1185.333	3914	
Obs-Exp	-72.333	191.667	-119.333		
				X2	
Sum Sq/Exp	8.021	56.315	21.830	86.166	
Upper Tail Areas					
Degrees of Freedom	0.05				
df =3	5.991				
Null	Reject				
Non-Printers Iguana	HA	HB	HC	Marginal 1	No Diff
Observed	50	108	35	193	207
Expected	64.333	64.333	64.333	193	
Marginal 2	114.333	172.333	99.333	386	
Obs-Exp	-14.333	43.667	-29.333		
				X2	
Sum Sq/Exp	3.193	29.639	13.375	46.207	
Upper Tail Areas					
Degrees of Freedom	0.05				
df =3	5.991				
Null	Reject				
Non-Printers Cougar	HA	HB	HC	Marginal 1	No Diff
Observed	44	164	60	268	132
Expected	89.333	89.333	89.333	268.000	
Marginal 2	133.333	253.333	149.333	536.000	
Obs-Exp	-45.333	74.667	-29.333		
				X2	
Sum Sq/Exp	23.005	62.408	9.632	95.045	
Upper Tail Areas					
Degrees of Freedom	0.05				

df =3	5.991				
Null	Reject				
Non-Printers Leaf	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	106	62	83	251	149
Expected	83.667	83.667	83.667	251.000	
Marginal 2	189.667	145.667	166.667	502.000	
Obs-Exp	22.333	-21.667	-0.667		
				X2	
Sum Sq/Exp	5.961	5.611	0.005	11.578	
Upper Tail Areas					
Degrees of Freedom	0.05				
df =3	5.991				
Null	Reject				
Non-Printers Spools	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	71	59	73	203	197
Expected	67.667	67.667	67.667	203.000	
Marginal 2	138.667	126.667	140.667	406.000	
Obs-Exp	3.333	-8.667	5.333		
				X2	
Sum Sq/Exp	0.164	1.110	0.420	1.695	
Upper Tail Areas					
Degrees of Freedom	0.05				
df =3	5.991				
Null	Fail to Reject				
Non-Printers Hallway	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	60	100	46	206	194
Expected	68.667	68.667	68.667	206.000	
Marginal 2	128.667	168.667	114.667	412.000	
Obs-Exp	-8.667	31.333	-22.667		
				X2	
Sum Sq/Exp	1.094	14.298	7.482	22.874	
Upper Tail Areas					
Degrees of Freedom	0.05				

df =3	5.991				
Null	Reject				
Printers Iguana	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	15	71	71	157	88
Expected	52.333	52.333	52.333	157.000	
Marginal 2	67.333	123.333	123.333	314.000	
Obs-Exp	-37.333	18.667	18.667		
				X2	
Sum Sq/Exp	26.633	6.658	6.658	39.949	
Upper Tail Areas					
Degrees of Freedom	0.05				
df =3	5.991				
Null	Reject				
Printers Cougar	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	39	127	35	201	44
Expected	67	67	67	201	
Marginal 2	106	194	102	402	
Obs-Exp	-28	60	-32		
				X2	
Sum Sq/Exp	11.701	53.731	15.284	80.716	
Upper Tail Areas					
Degrees of Freedom	0.05				
df =3	5.991				
Null	Reject				
Printers Leaf	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	63	54	51	168	77
Expected	56	56	56	168	
Marginal 2	119	110	107	336	
Obs-Exp	7	-2	-5		
				X2	
Sum Sq/Exp	0.875	0.071	0.446	1.393	
Upper Tail Areas					
Degrees of Freedom	0.05				
df =3	5.991				

Null	Fail to Reject				
Printers Spools	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	59	46	36	141	104
Expected	47	47	47	141	
Marginal 2	106	93	83	282	
Obs-Exp	12	-1	-11		
				X2	
Sum Sq/Exp	3.064	0.021	2.574	5.660	
Upper Tail Areas					
Degrees of Freedom	0.05				
df =3	5.991				
Null	Fail to Reject				
Printers Hallway	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	73	53	43	169	76
Expected	56.333	56.333	56.333	169	
Marginal 2	129.333	109.333	99.333	338	
Obs-Exp	16.667	-3.333	-13.333		
				X2	
Sum Sq/Exp	4.931	0.197	3.156	8.284	
Upper Tail Areas					
Degrees of Freedom	0.05				
df =3	5.991				
Null	Reject				
Printers w/ Corrected Vision Iguana	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	3	46	32	81	54
Expected	27	27	27	81	
Marginal 2	30	73	59	162	
Obs-Exp	-24	19	5		
				X2	
Sum Sq/Exp	21.333	13.370	0.926	35.630	
Upper Tail Areas					

Degrees of Freedom	0.05				
df =3	5.991				
Null	Reject				
Printers w/ Uncorrected Vision Iguana	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	7	14	33	54	17
Expected	18	18	18	54	
Marginal 2	25	32	51	108	
Obs-Exp	-11	-4	15		
				X2	
Sum Sq/Exp	6.722	0.889	12.5	20.111	
Upper Tail Areas					
Degrees of Freedom	0.05				
df =3	5.991				
Null	Reject				
Printers Male Iguana	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	7	40	47	94	46
Expected	31.333	31.333	31.333	94	
Marginal 2	38.333	71.333	78.333	188	
Obs-Exp	-24.333	8.667	15.667		
				X2	
Sum Sq/Exp	18.897	2.397	7.833	29.128	
Upper Tail Areas					
Degrees of Freedom	0.05				
df =3	5.991				
Null	Reject				
Printers Female Iguana	**HA**	**HB**	**HC**	**Marginal 1**	**No Diff**
Observed	2	20	18	40	25
Expected	13.333	13.333	13.333	40	
Marginal 2	15.333	33.333	31.333	80	
Obs-Exp	-11.333	6.667	4.667		
				X2	
Sum Sq/Exp	9.633	3.333	1.633	14.6	
Upper Tail Areas					

Degrees of Freedom	0.05				
df =3	5.991				
Null	Reject				

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Other Notes

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